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Lolo Creek Habitat Improvement

Annual Report FY 1984

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I. ACKNOWLEDGEMENTS:

The success of the 2 year project in Lolo Creek, was made possible by the team effort provided by everyone involved in the project. However, a few special people deserve acknowledgement.We would like to say thanks to our friend and crew leader, Bob Vogelsang.We would like to thank Paul Brouha, for his continued support, first from the R1 Regional Office and now from the Chief 's Office in Washington D.C. Ray Coon, owner of our contract heavy equipment and the equipment operator, Wendell Osborne, also deserve a thank you for a job well done.

A special thanks again goes to Larry Everson, BPA Contracting Officer, for his encouragement, support, and insight throughout the project.

II. INTRODUCTION

In 1984, and under the auspices of the Northwest Power Planning Council, the Clear-water National Forest and the Bonneville Power Administration entered into a contractual agreement to improve anadromous fish habitat in Lolo Creek. This was to be the second and final year of instream enhancement work in Lolo Creek, a major tributary to the Clearwater River. The project was again entitled Lolo Creek Habitat Improvement (#84-6) which was scheduled from April 1, 1984, through March 31, 1985. Project costs were not to exceed $39,109.

The following report is a description of the project objectives, methodology, results, and conclusions of this year’s work, based on the knowledge and experience gained through 2 years of enhancement work.

A. Project Objectives:

1. Primary Objectives: The primary objective was to partially mitigate the juvenile and adult anadromous fish losses accrued through hydroelectric development in the Columbia and Snake River systems by enhancing the spawning and rearing habitats of selected Clearwater River tributaries for spring chinook salmon and summer steelhead trout. The enhancement was designed to ameliorate the “limiting production factors” by the in-stream placement of habitat structures that would positively alter the pool-riffle structure and increase the quality of over-winter habitat.

2. Lolo Creek Objectives

a. Enhance 40 to 60 acres of summer and winter rearing habitat.

b. Enhance the quality of 10 to 14 acres of spawning habitat.

c. Increase the utilization and productive capability of the habitat over a 12 mile reach.

d. Increase the diversity (number of niches) of the rearing habitat.

e. During low escapement periods, increase the seeding capability of the system by increasing the amount of hiding and escape cover for adult spawners.

f. Increase the smolt production capability of the habitat to a level that an annual increase of 4,000 steelhead and 10,000 salmon smolts is realized within two escapement cycles and sustained thereafter.

B. Description of Project Area:

A complete and thorough description of the project area is presented in the 1983 Annual Report for the "Lolo Creek and Upper Lochsa Habitat Enhancement Projects", submitted to the Bonneville Power Administration by F. A. Espinosa, Jr., 1984.

III. METHODS AND MATERIALS:

A. Basis for Treatment of Choice:

The 1983 annual report (Methods and Materials Section, page 16) discusses the factors limiting the system's inherent capability to produce fish, our ability to enhance these factors, and the treatment of choice or structure-type used to obtain the desired results.

B. Pre-implementation Phase:

The pre-implementation phase began much as it had in 1983, by first attempting to identify reaches needing treatment and then deciding on the appropriate treatment. Although this can be accomplished on aerial photos it is best done in the field with "map in hand." Due to the proximity of the 100 and 103 roads to Lolo Creek, we were able to complete mapping the treatment reaches by June 1, 1984.

Each reach was marked and the treatment to be applied recorded on 36 inch surveyor stakes. Necessary project resources, such as boulder sources, were also marked in this manner. By mid-June a working project map was completed. Access points for heavy equipment were also mapped. The final portion of this phase involved orientating the crew and other Forest support personnel to the Fy 84 project.

C. Implementation Phase:

1. Mitigation and Maintenance of the 1983 Project:

On May 7, 1983, we began planting 2,000 bare-root aspen shoots obtained from Native Plants Nursery in Sandy, Utah. Since we had constructed 40 log weirs or K-dam structures in 1983, we planned to plant 100 shoots per structure or 50 on each bank. A two person crew completed the work on May 25, 1984. The crew averaged 133 shoots per day. The total cost for this was $3,600. The aspen were planted to prevent erosion, stabilize the site, provide future shade and add quality deciduous debris to the system (figures 1 and 2).

The Forest was allocated $5,000 for maintenance of last years structures. Maintenance work involved both hand and equipment work and was carried out in an orderly process coupled with the new construction. Table 1 lists the type of maintenance problems we encountered and the cost of maintaining these structures.

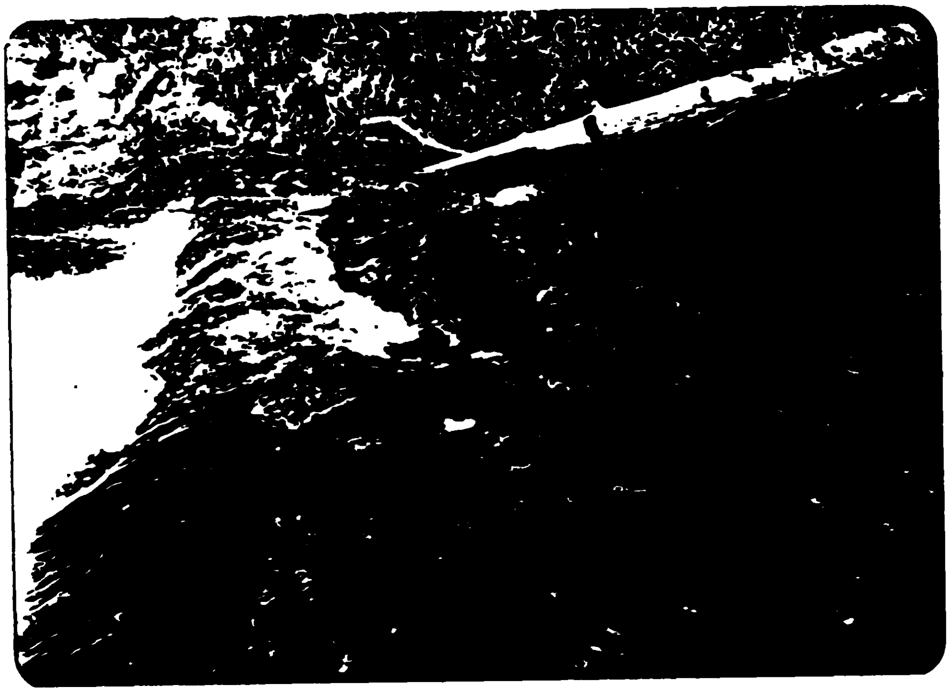
Sixteen percent of all the structures installed in Lolo Creek in 1983, required some maintenance (Table 1). Eight percent of the structures required major maintenance utilizing heavy equipment to correct the situation and prevent further maintenance. Fifteen percent of all structures required minor hand maintenance usually involving the wire on the upstream side of a log structure. The average cost of maintenance was $14O/structure. Maintenance costs ranged from $50 to $500 per structure (Table 1). K-dams and log weirs required 100 percent of the maintenance. These structure types involved 26 percent of the total structures installed in 1983. Sixty-seven percent of the K-dams and 42 percent of the log weirs required some maintenance (Table 1).

TABLE 1

Maintenance Conditions

Structure Types	# Needing Maintenance	Cost of Maintaining Each Structure	Conditions Requiring Maintenance
K-dams	5	$250	Gravel washed out of wing cribs.
	2	$30	Wire settled in at log-wire junction.
Log Weirs	11	$100	Wire peeled back toward log from upstream end (Figure 3).
	3	$250	Bank erosion. Water washing around the end of the log.
	1	$500	Complete dis-placement of structure from site.
	5	$50	Wire settling on upstream side of the log.
	1	$250	Large debris catching on log and deflecting flows into bank (Figure 4).
		$50	Beaver const-ructing dams on structures.

Figures 1 and 2. Upper photo shows crewman planting aspen shoots. Note bucket full of shoots. Lower photo shows planted aspen shoots.



Figures 3 and 4. Upper photo shows typical maintenance problem of wire peel. Lower photo shows crawler backhoe resealing log weir.

Figures 5 and 6. Upper photo shows backhoe filling in “high water wing” added to existing log weir. Lower photo shows crew pinning “high water wing" to log weir.

No maintenance was required for: root wads, boulder clusters, felled organic debris, deflector logs, bank cover devices, or lateral deflectors. Appendix A is a project map showing those structures constructed in 1983, which required maintenance. Figures 3 and 8 show some of the maintenance work.

2. 1984 Construction:

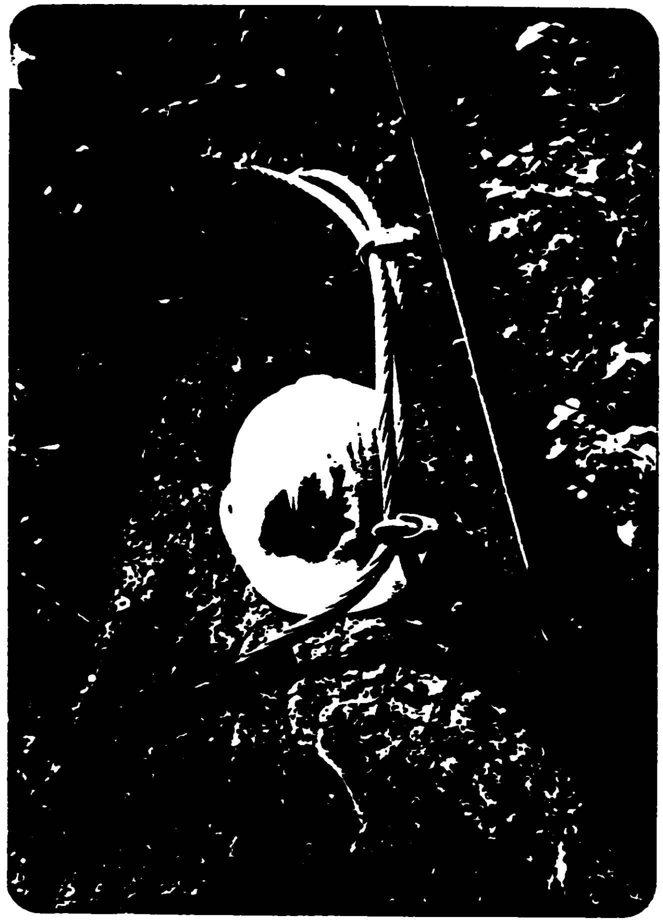
On June 18, 1984, the Lolo project for this year began. Our first job was gathering cable of 9/16 inch diameter located at old cable logging landings. Since we were going to treat a 1 mile reach with large organic debris (tree over 24" DBH), we felt the larger cable was necessary to hold these felled trees during peak flows. We gathered over 2,000 feet of cable in 2 weeks. The crew then felled trees for log weirs, K-dams, and K-dam wings. We were fortunate this year in that each site had a good supply of trees, so that no hauling was necessary.

Next the crew felled and cabled large conifers in the debris reach. Figures 9 and 17 show the technique used in felling and cabling these large trees. Appendix B shows the site and species of the debris within the reach. In all, 21 trees were felled and cabled (Figures 14 through 18). We could have accomplished more, however, some stretches within the reach were sparsely vegetated with riparian conifers and we felt it best to leave them. The treatment reach lacked pools and was dominated by 95 percent run, over large cobble-sized basalt. Trees were felled in the same manner as described in the 1983 annual report (page 60).

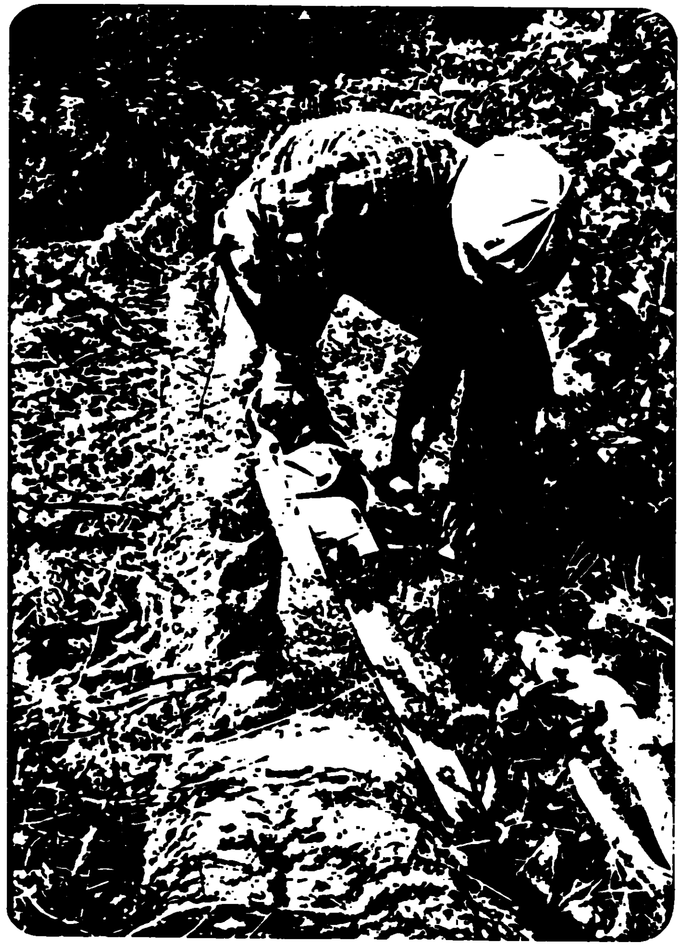
The next phase of the project involved excavating and hauling large boulders for weirs, boulder clusters and large single boulder placements. Boulders were excavated and loaded with a Case-966 front-end loader and hauled with a dual axle 12 yard dump truck. Over 250 boulders were excavated, hauled, and dumped at the predetermined locations, during the week of July 23-27. The 966 loader could not work while the dump truck was hauling; we used a single operator for both pieces of equipment.

On August 6, 1984, we began maintenance work on the structures with the Link Belt-4500 crawler backhoe. Concurrently, a second crew began construction of bank cover devices. These overhead cover devices are a modified version of those used in Wisconsin to restore deteriorated streambanks (see Appendix C). Over a 4 week period 7 K-dams, 4 log weirs, 7 boulder weirs, 7 boulder clusters, 185 large boulders, 1 boulder deflector, 7 root wads, 7 deflector logs, and 8 bank cover devices were constructed or installed in Lolo Creek. In addition, 2 debris jams were removed. Figures 18 through 59 illustrate this year's activities.

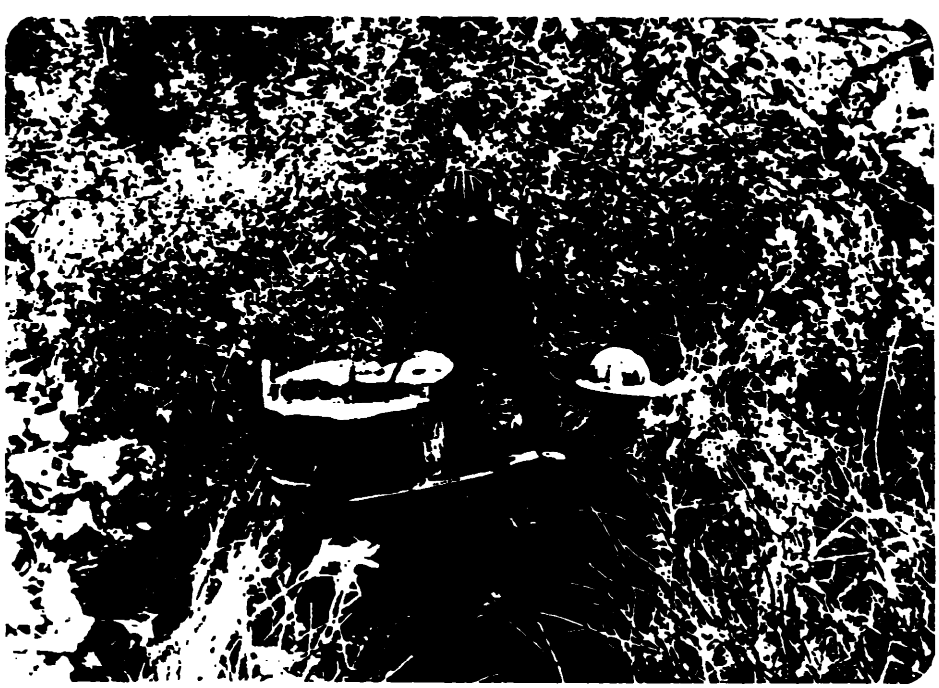
Selection of logs for K-dams and log weirs, selection of boulders for boulder clusters, and placement of root wads, boulders, boulder clusters, and deflector logs as well as construction techniques are adequately



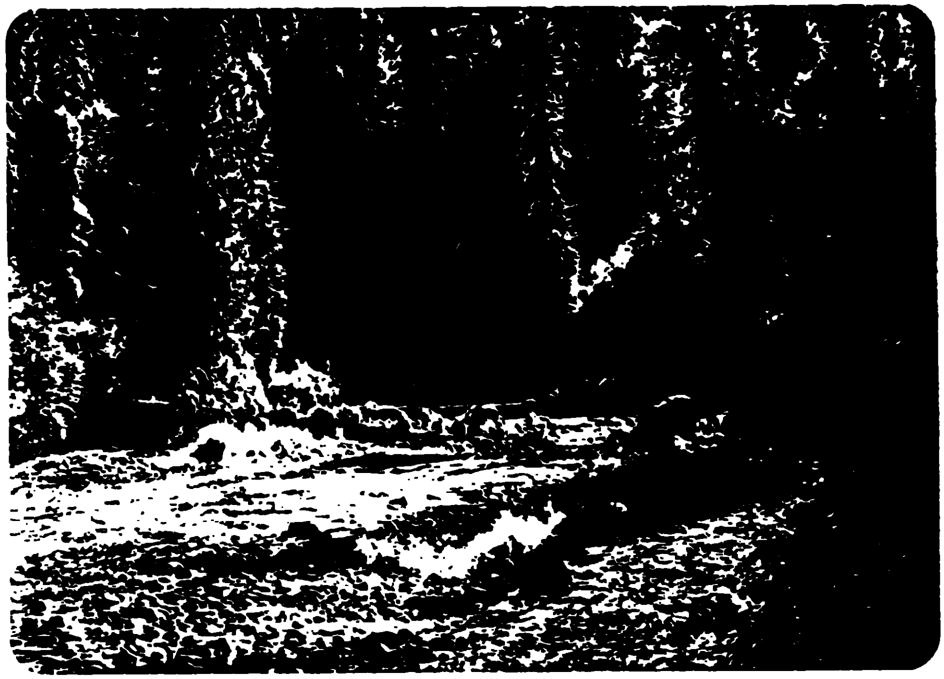
Figures 9 and 10. Upper photo shows cable attachment to log. Lower photo shows technique of cabling prior to falling.



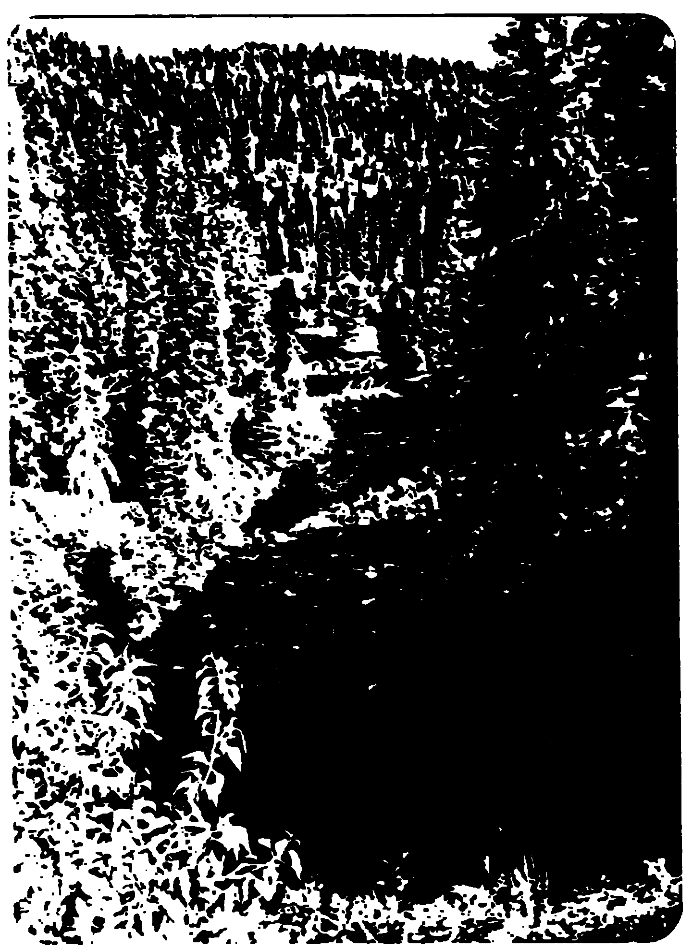
Figures 11 and 12. Upper photo shows crewman notching log to accept wing.
Lower photo shows crewman notching stump to accept cable.



Figures 13 and 14. Upper photo shows crewman walking on felled debris with cable. Lower photo shows 1 felled tree and 1 tree falling in.



Figures 15 and 16. Upper and lower photo show arrangement of felled organic debris.



described in the 1983 Annual Report (pages 34-60). The exception is the improvements we have made in the design and construction of K-dams. These improvements are designed to increase the longevity and eliminate costly maintenance. Appendix D, Figures 18 and *19* show the improvements in design made to eliminate the loss of rip-rap from the downstream cribs.

Construction of new structure types not included in the 1983 description includes; overhead bank cover devices, boulder deflectors and weirs. Figures 40 through 48 show the construction of the overhead bank over devices l This modification of the streambank structure used in Wisconsin is designed to stablize banks and to provide overhead cover. Each one was constructed at a site where active bank cutting was evident, or an existing undercut occurred.

By constructing some of the overhead cover devices against eroding banks and rip-rapping the bank under the structure, the hydraulic energy that was eroding the bank will be diverted to scouring a pool at the site. If no pool forms, then a pool forming structure, such as a boulder or deflector log, can be placed near the structure. By constructing the other bank structures on an existing undercut bank within meanders, the undercut effect was extended.

The single boulder deflector is similar to a log deflector in function. Seven large boulders keyed into a talus stream bank were placed side-to-side into the stream at a 35 degree angle. A small pool and gravel bar exist off the point of the deflector some 35 feet out from the bank.

A total of 7 boulder weirs were constructed. Boulder weirs perform the same function as log weirs except that no bank disturbance is required. Both straight and v-shaped weirs were constructed. Boulder weirs were used where pool formation was desirable but bank disturbance was undesirable or impractical. Figures 49 and 50 show typical boulder weirs.

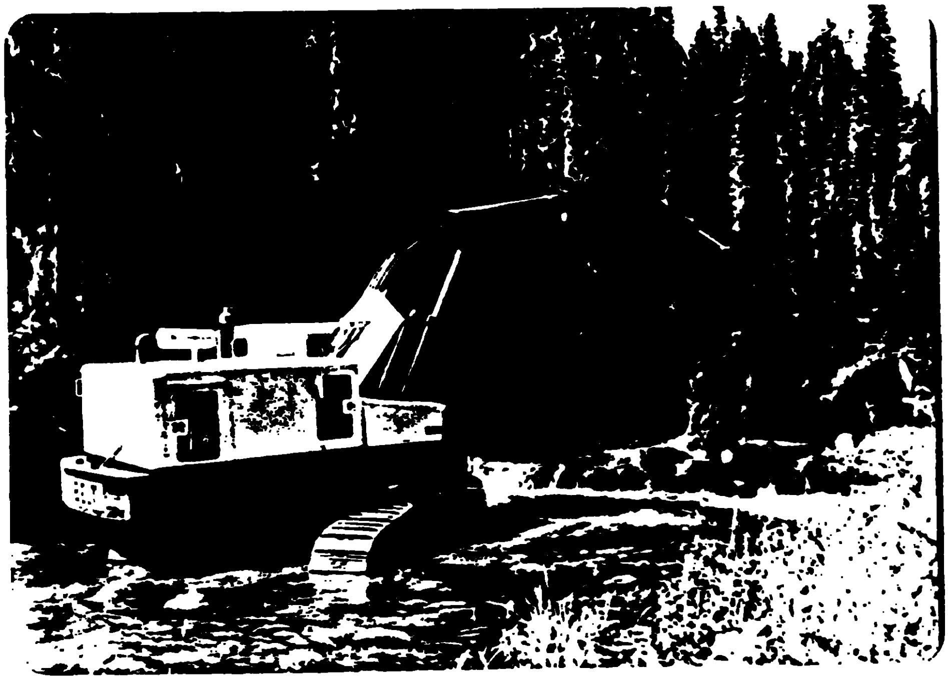
Two large debris jams causing excessive ponding and tremendous sediment deposition were removed with the crawler backhoe. The braided side channels created by these jams were preserved as well as their water supply. Figures 51 through 55 show the activities associated with removing these jams.

One very large K-dam was constructed (map #50, Appendix E). This log was a 42 inch DBH western white pine, spanning the channel 90 feet from wetted edge to wetted edge. The large size was necessary to withstand the force of high flows in this reach. Figures 56 through 59 illustrate this structure.

D. Post-Construction Phase:

The post construction phase in Lolo Creek ended on September 28, 1984. For the remainder of the work period, the crew worked on restoration of disturbed sites created by project activities. These sites included

Figures 18 and 19. Upper and lower photo show completed K-dams and modified wing supports.



Figures 22 and 23. Upper and lower photos show backhoe filling in main log weir.

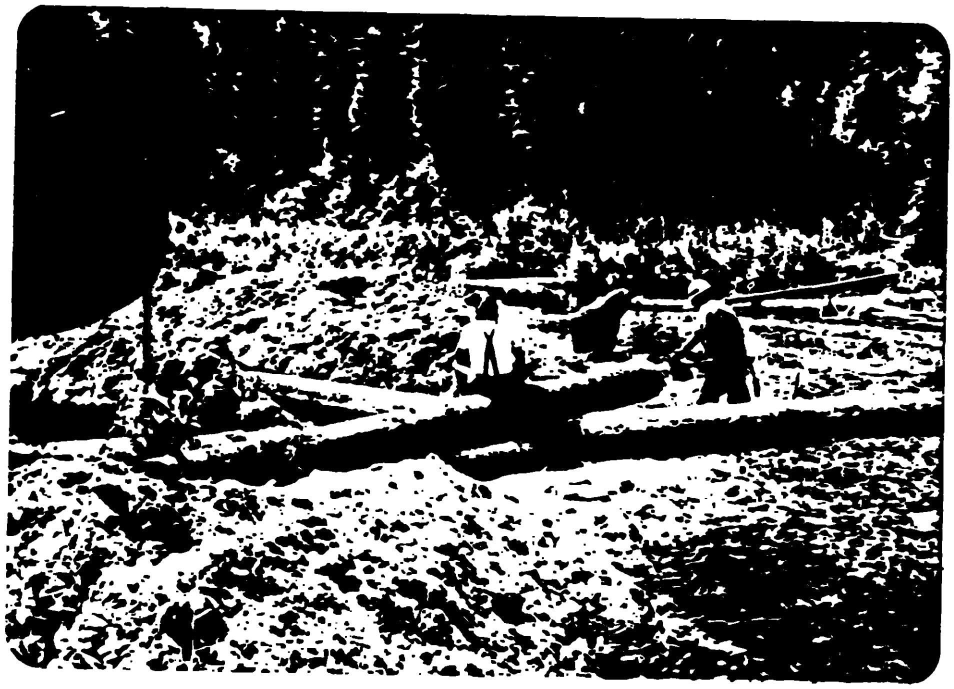
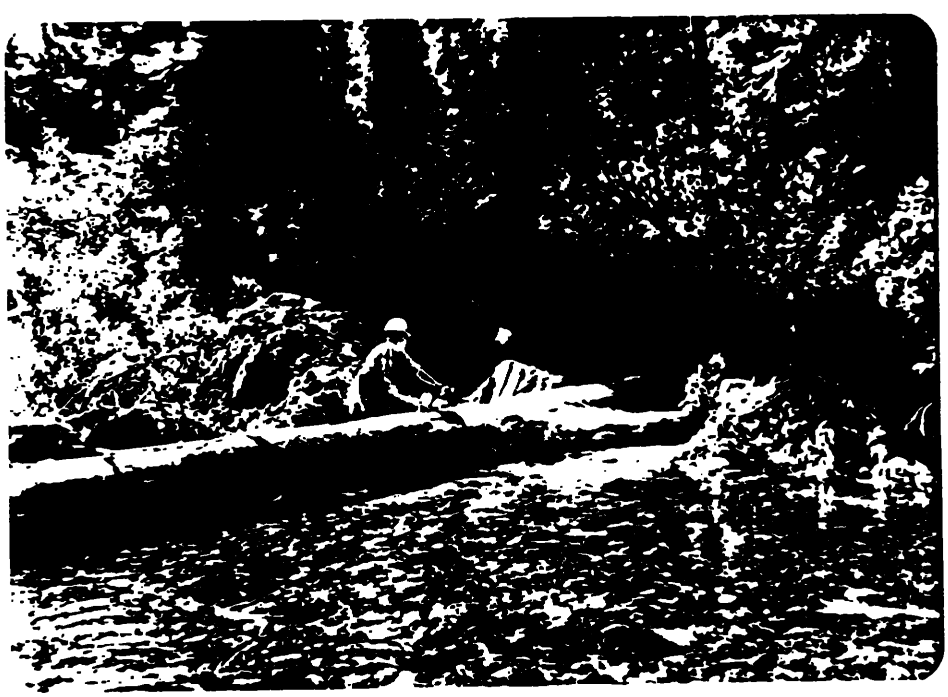


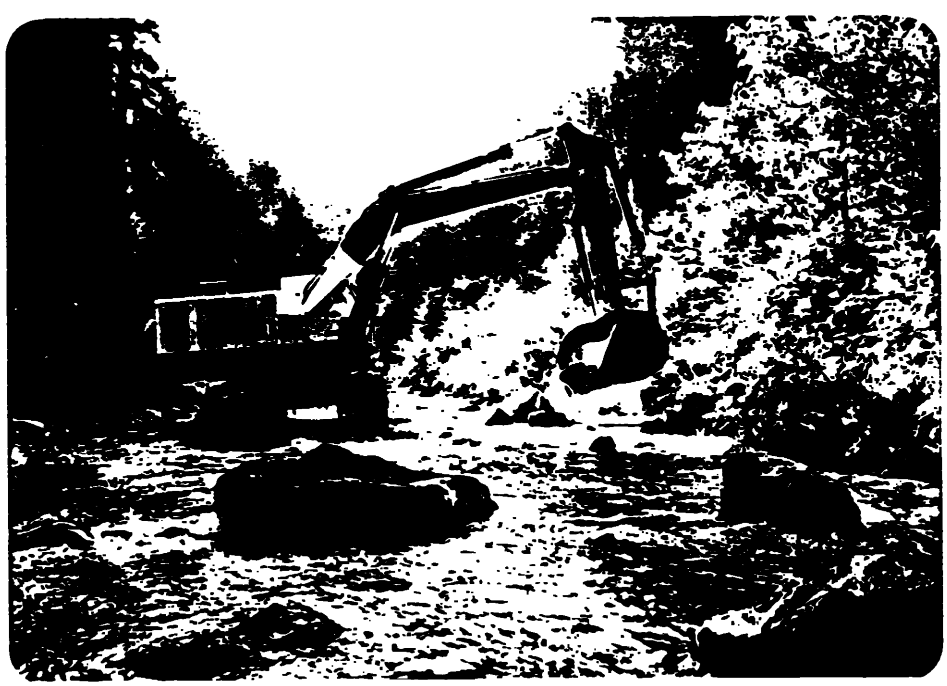
Figure 26. Upper photo show crewman working on wing supports. Note size of materials.

Figures 27 and 28. Upper photo shows crewman pinning wing support. Lower photo shows crewman cutting notch to accept wing support.

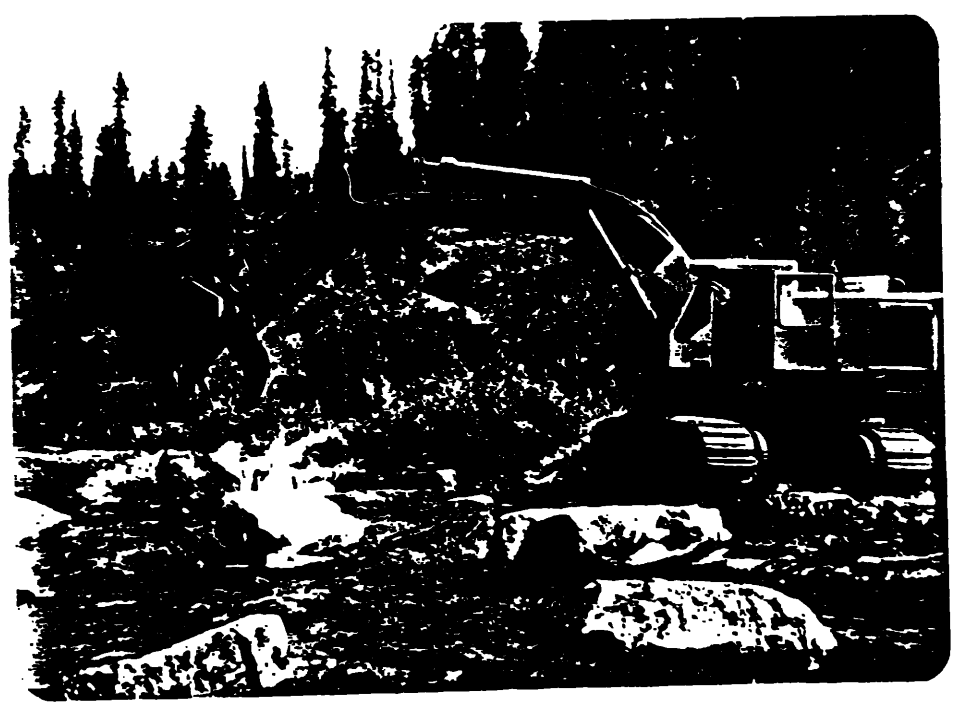


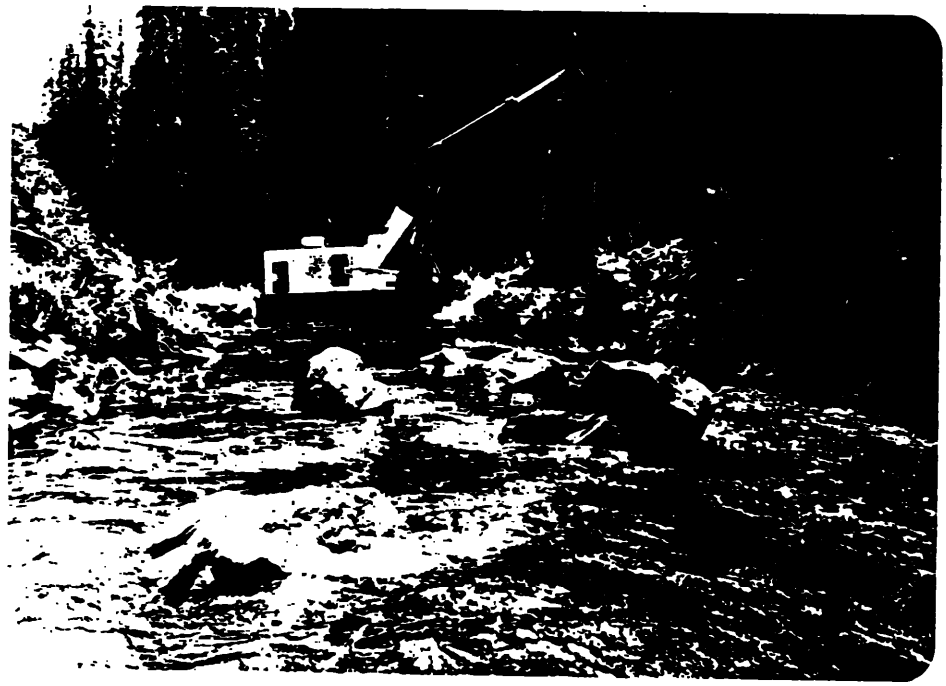
Figures 31 and 32. Upper and lower photos show backhoe moving white pine stump into place.

Figures 33 and 34. Upper photo shows backhoe positioning cedar stump. Lower photo shows backhoe and nearly completed boulder reach.



Figures 35 and 36. Upper and lower photos show backhoe working on large boulder reaches, in Lolo Creek.



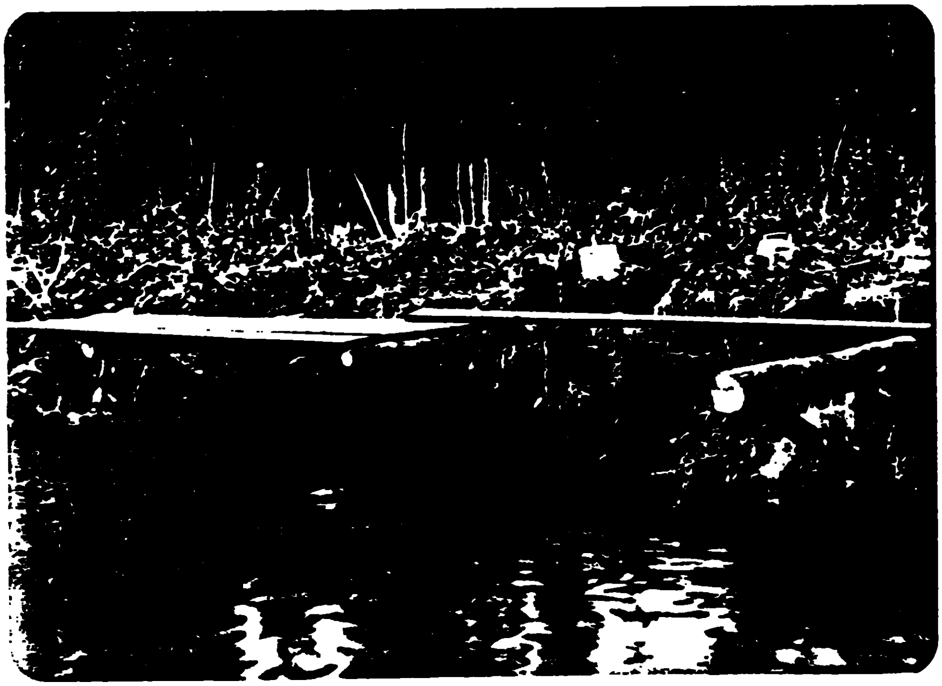


Figures 36 and 37. Upper and lower photos show backhoe working on large boulder reaches.

Figures 38 and 39. Upper and lower photos show completed boulder reaches.

Figures 40 and 41. Upper and lower photos shows typical sites for overhead cover devices, in Lolo Creek.

Figures 42 and 43. Upper and lower photos show the emerging support structure for the overhead cover device. Note rip-rap on bank.



Figures 44 and 45. Upper and lower photos show the planking (2" x 10" X 10') used on overhead cover devices.

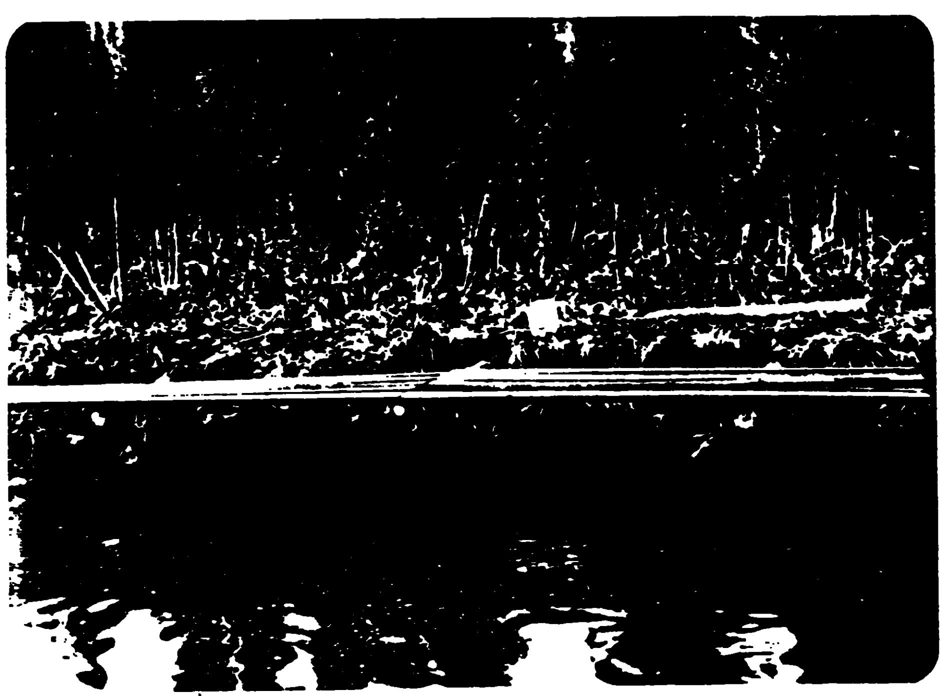


Figure 46. Photo shows planking covered with a layer of gravel topped with native sod.

Figures 47 and 48. Upper and lower photos show completed overhead cover devices.

access, egress, and travel routes for the backhoe, boulder excavation, riparian zone, and stream bank disturbances at structure sites. These areas were water barred, seeded or both. We plan to continue the successful phase of spring aspen planting at log weir and K-dam sites.

IV. RESULTS AND DISCUSSION:

A. 1984 Project:

A total reach distance of 11 miles (extensive perspective, "area of influence") was enhanced with the construction and placement of 258 habitat structures. The actual stream distance treated with structures (intensive perspective, "non-treated" reaches excluded) equalled 3.9 miles. The average number of structures per unit distance was 23/mile (1 structure every 70M), of overall reach distance or 66/mile (1 structure every 24M) of actual distance treated. A map displaying the types, distribution, and concentration of structures is presented in Appendix E.

Sixty-five percent of the total project activity this year (168 structures) was concentrated in the reach below White Creek (5.75 miles), whereas 35 percent was in the 5.25 miles above White Creek (Appendix EL The low density of structures in the upper section was due to the 1983-1984 emphasis. Activity (69%) in 1983, was concentrated above White Creek so that this area was "filled-in" in 1984. In 1983, the section below White Creek was lightly treated or delayed to 1984. A categorization of total project activity in 1984 is presented in Table II along with the number of structures by type and the enhancement effects. Perusal of Table II indicates structures that create "pocket water", create pools and enhance cover were featured (74% of all structures. Significant secondary effects include channel scouring and recovery of stream banks.

K-dams and log weirs were concentrated in 2 reaches (7 out of 11 structures), the other 4 were widely spaced in the the reach above White Creek or used as a main pool forming structure in conjunction with other structure types. Single boulder weirs were used singly twice and in 2 main reaches, one with 2 boulder weirs, the other with 3 weirs. Those reaches treated with log weirs averaged 4 structures per reach over a mean distance of 1/2 mile.

Seven reaches were treated with a combination of large boulders and/or boulder clusters, ranging from 3 (l-cluster) to 52 with a mean of 20 per reach. Reach length ranged from 50 to 500 feet with a mean of 200 feet.

Boulder deflectors, root wads, deflector logs, and overhead bank cover devices were used singly or within reaches containing other structures or the specific site requirements for their installation.

Two debris jams were removed. However, the side channels created by these jams were maintained.

The organic debris reach was treated with 21 trees (refer to Appendix B). This reach was 1 mile long for an average distance between felled trees of 251 feet.

The contractual agreement with BPA called for a minimum of 120 structures. We exceeded this goal by 115 percent or 138 structures. This was made possible by the emphasis on boulders this year, which were easily obtained and installed. Other time-efficient and cost-effective measures were discussed in the 1983 annual report (page 66). Table IV displays the cost analysis of the 1984 project.

B. Results of the Total In-stream Structural Enhancement (1983-84):

A total of 11 miles of Lolo Creek was intensively treated over the 2 year period. A grand total of 392 structures were constructed or placed in Lolo Creek (refer to Appendix F for specifics).

Scrutiny of Table III reveals that structures creating "pocket water" were emphasized (63%). Pool formation structures were the next highest emphasis at 25 precent and cover enhancement structures next at 12 percent. Treatment emphasis was correlated to the pretreatment pool:riffle ratio of 23:77. Boulder placements were used to enhance continuous riffle reaches.

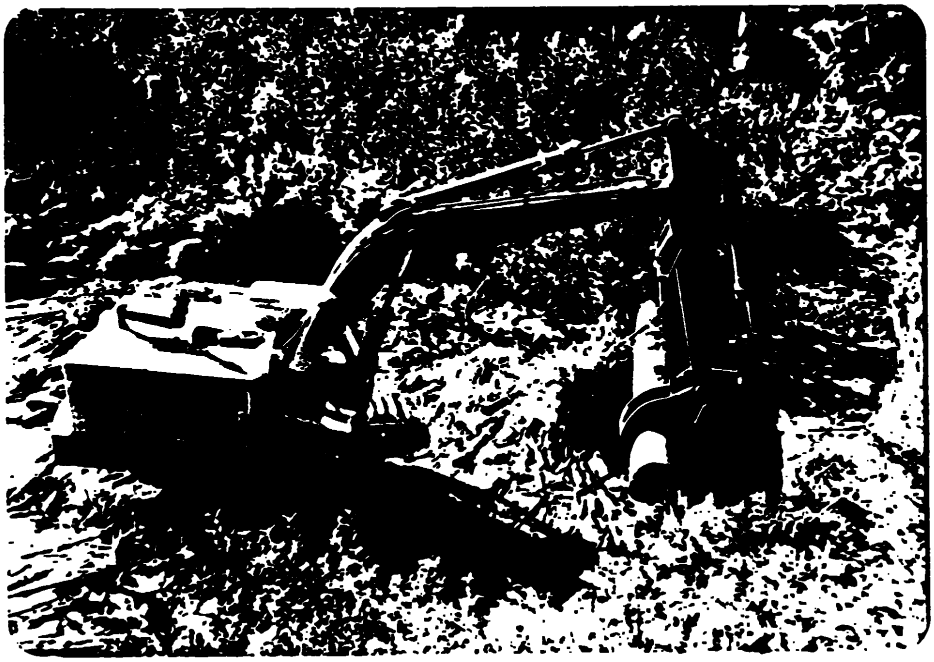
In essence, the primary objectives of this enhancement project were to more favorably alter the pool:riffle structure and increase the diversity (quality) of the habitat. In our opinion, we have achieved those objectives via our enhancement design for Lolo Creek.

Overall we contracted for 216 structures and we completed 392. Table V displays the cost analysis for the entire project.

C. Monitoring of 1983 Enhancement:

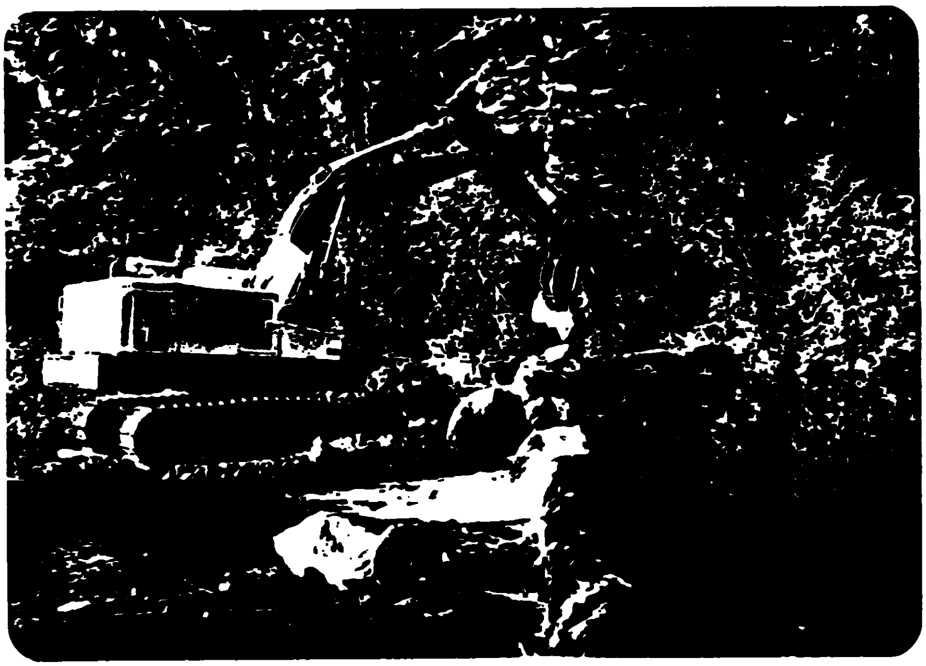
On July 30 and August 29, 1984, Forest Service biologists conducted some limited evaluation of the habitat structures that were installed in 1983. The evaluation consisted of population sampling of enhanced and nonenhanced habitats via snorkel diving. Ten pools (upstream and downstream) formed by log weirs, two reaches of boulder clusters, and four control reaches (nonenhanced) were sampled. Sampling units and controls were not randomly selected, but were representative of the type of enhancement work conducted in 1983. Control units were selected within the same overall stream reach and were typical of habitat that the project would have enhanced. Because of time constraints, no

Figures 51 and 52. Upper and lower photos show the 2 debris jams removed in 1984.



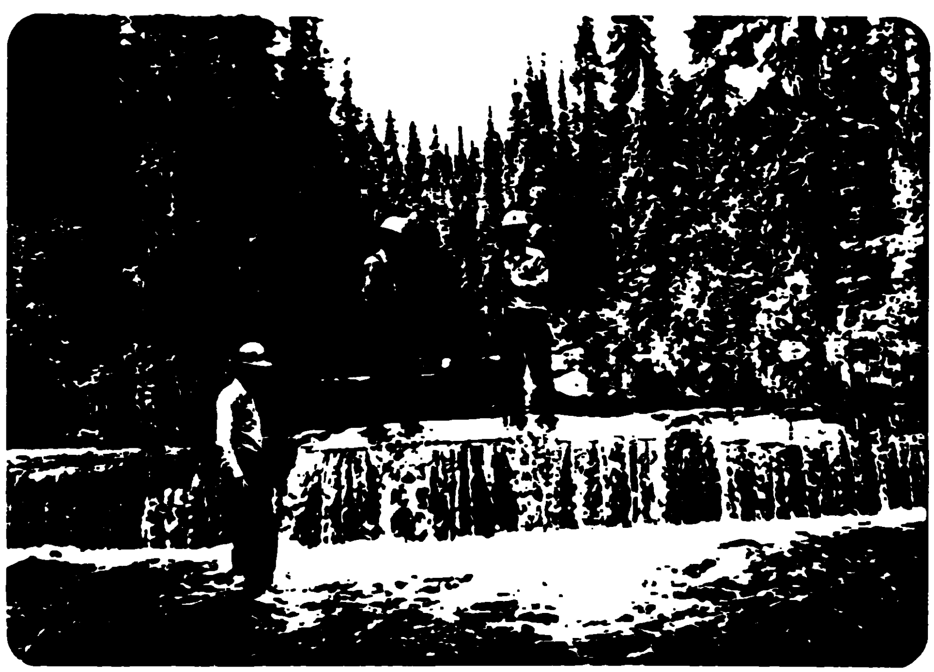
Figures 53 and 54. Upper and lower photos shows the backhoe working on the debris jams.

Figure 55. Photo shows site after jam removal. Note sand dunes upstream from site.



Figures 56 and 57. Upper and lower photos show backhoe working on large log weir.

Figures 58 and 59. Upper and lower photos show completed weir.



boulder cluster controls were sampled. In essence our methodology was similar to that employed by the State's evaluation team. We sampled a total of 3,591m^2 of enhanced habitat and 1,017m^2 of nonenhanced habitat (controls). For all reaches and types of structures, the enhanced ("E") vs nonenhanced ("NE") fish densities were: juvenile steelhead (1+ and 2+'s) "E" = 8/100m^2 vs "NE" = 6/100m^2; and salmonid fry "E" = 1/100m^2 vs "NE" = 0/100m^2.

When the summary data are stratified by sampling period and structure-type, some interesting comparisons are revealed. In late July, weir- pools displayed a chinook density of 12/100m as opposed to 4/100m for the nonenhanced habitat (300 percent increase). This increase was not reflective of combined juvenile steelhead---i.e. "E" = 9/100m^2 vs "NE" = 10/100m^2. However, there was a 180 percent increase in Age 2+ steelhead when comparing enhanced vs nonenhanced. This would be expected as we are dealing with a larger fish that would require more "classical" pool habitat. Salmonid fry densities were low in all sample units, therefore, differences were insignificant.

Sampling of boulder clusters revealed juvenile chinook densities similar to those observed in weir pools: 12/100m^2 for weir pools vs 11/100m^2 for boulders. Total juvenile steelhead did show a substantial difference between structure-types: 9/100m^2 for weir pools vs 16/100m^2 for boulders. This also is expected since steelhead seem to prefer the "pocket water" habitat that boulder clusters create. Although not directly comparable, densities of salmon and steelhead were much higher in the boulder reaches vs the controls (salmon = 300 percent and steelhead = 160 percent). A summary comparison for the July period shows density ratios of salmon and steelhead in enhanced vs nonenhanced habitats as 31 and 1.2:1 respectively.

In late August and at different sites, densities of juvenile salmon and steelhead were very similar in enhanced (weir pools) vs nonenhanced habitats: "E", chinook = 22/100m^2 vs. "NE", 24/100m^2 and "E", steelhead = 5/100m^2 vs "NE", 6/100m^2.

Comparison of July and August data has provided some mixed results. The sampling was limited in scope and intensity. This data may only serve as a comparative adjunct to the more intensive and comprehensive effort conducted by the State evaluation team. Data collected and analyzed by the evaluation team indicated a signif icant (300 percent) increase in Age 2+ steelhead density in log weir pools vs. controls (Petroskey, pers. comm., 1984). Albeit limited, our data (July) suggests that the same relationship (300 percent increase) may exist for juvenile chinook in log weir pools. In any case, adequate evaluation of the project will require a minimum effort of 5 years.

SUMMARY AND CONCLUSIONS

1983-1984 Instream Enhancement

1. In FY 1983, Phase I of the Lolo Creek Project was Initiated and Completed.

a. The project (#83-522) was funded at $27,000.

b. One-hundred percent of the budget was expended in executing the project.

c. A total of 145 structures were placed in Lolo Creek at an average cost of $186/structure.

d. Eighty-seven percent of the structures were designed to improve pool frequency and quality.

e. A total stream distance of 8.5 miles was enhanced with emphasis on the 5.25 miles above White Creek.

2. In FY 1984, Phase II of the Lolo Creek Project was Initiated and Completed.

a. The project (#84-6) was funded at $39,109, plus $5,000 for maintenance of 1983 structures.

b. One-hundred percent of the budget was expended in executing the project.

c. A total of 258 structures were placed in Lolo Creek at an average cost of $152/structures.

d. Seventy-four percent of the structures were designed to create "pocket water" and enhance cover.

e. A total stream distance of 11 miles was treated with emphasis on the 5.75 miles below White Creek.

3. A total stream distance of 11 miles in Lolo Creek was intensively enhanced over a 2 year period with a total of 392 structures constructed or installed.

a. Average distance between structures for the 11 miles was 168 feet.

b. Average cost per structure over the 2 year period was $169.

Structures which diversified long riffle/run reaches by adding "pocket water" pools were emphasized (63% of all structures).

d. The structures were targeted at enhancing the baseline pool/riffle ratio of 23:77 to a more "classic" 40:60 to 50:50 ratio. The degree of enhancement equates to 50 acres of summer/winter rearing habitats and 12 acres of spawning habitat.

4. In our opinion we have increased the diversity, utilization, and production capability of Lolo's fish habitat with this project.

a. Preliminary evaluations by biologists from both the Idaho Department of Fish and Game and biologists on the Clearwater National Forest show that juvenile chinook and age 2+ steelhead, prefer the enhanced habitat of log weir pools.

b. Whether or not we achieve the estimated increase in salmon and steelhead smolt production (10,000 chinook and 4,000 steelhead) is a matter for evaluation by the Idaho Department of Fish and Game and the Bonneville Power Administration.

5. We feel that the 1984 project was even more successful than the 1983 project. Numerous groups of resource people have viewed the Lolo Creek project, both inter- and intra-agency personnel. For the most part we have received only positive responses during these reviews.

6. In September 1984, adult spawning spring chinook salmon were seen utilizing the spawning habitat created and enhanced by the structures.

V. <u>APPENDICES</u>:

Appendix A	Map of structures requiring maintenance.
Appendix B	Distribution of felled large organic debris.
Appendix C	Classic (Wisconsin type) bank cover device.
Appendix D	K-dam wing joint and crib reinforcement improvements.
Appendix E	1984 project map.
Appendix F	1983-1984 combined project map.
Appendix G	Explanation of yearly map totals and final map total (differences).

Table II

Types of habitat structures, number per type, and probable enhancement effects of structures placed in Lolo Creek, Idaho (1984).

Type	No.	Probable Effect
K-dams	7	Pool formation and sediment reduction.
Log weirs	4	Pool formation and sediment reduction.
Boulder weirs	7	Pool formation and sediment reduction.
Individual Boulder Clusters	4	"Pocket water" pool formation cover enhancement and sediment reduction.
Single large boulders	5	"Pocket water" pool formation cover enhancement and sediment reduction.
Boulder Reaches (large boulders and clusters)	183	"Pocket water" pool formation cover enhancement and sediment reduction.
Boulder Deflector	1	Pool formation, sediment reduction, gravel bar maintenance and cover enhancement.
Cedar Root Wads	7	Cover enhancement and pool formation.
Organic Deflector Logs	7	Pool formation, sediment reduction and cover enhancement.
Rank Cover Devices	8	Cover enhancement and bank stabilization.
Large Anchored Organic Debris	73	Pool formation, sediment reduction and cover enhancement.
TOTAL	258	

Table III

Total (1983-84) types of habitat structures, number per type, and probable enhancement effects of structures placed in Lolo Creek, Idaho.

Type	No.	Probable Effect
K-dam	16	Pool formation and sediment reduction.
Log Weirs	30	Pool formation and sediment reduction.
Boulder Weirs	7	Pool formation and sediment reduction.
Boulder Clusters	9	"Pocket water", pool formation, cover enhancement and sediment reduction.
Boulder Deflector	1	Pool formation, sediment reduction, gravel bar maintenance, and cover enhancement
Cedar Root Wads	21	Cover enhancement and pool formation.
Lateral Deflector Logs	14	Cover enhancement and pool formation.
Pool Construction	1	Pool Formation
Bank Cover Devices	12	Cover enhancement and bank stabilization.
Debris Jam Removal	3	Sediment reduction and bank stabilization.
Large Anchored Organic Debris	42	Pool formation, cover enhancement and sediment reduction.
Large Individual Boulders	185	"Pocket water", pool formation, sediment reduction and cover enhancement.
Boulder Reaches	51	"Pocket water", cover enhancement, pool formation, and sediment reduction.
TOTAL	392	

Table IV

Project costs per unit structure type for habitat enhancement in Lolo Creek, Idaho (1984).

Structure Type	Unit Cost
K-dam (completed)	$1100
K-dam (modified) reduced wing structure	$900
Log Weir	$390
Boulder Clusters (x 2.5 boulders/cluster)	$25 ($10 per rock)
Large Individual Boulders	$10
Large Anchored Organic Debris	$48
Anchored Deflector Logs (near channel)	$32
Boulder Weirs	$200
Boulder Deflectors	$130
Root Wads	$60
Bank Cover Devices (Labor Intensive)	$1065
Debris Jam Removal (Equipment Intensive)	$826

Avg. Project Cost for all Structures $= \frac{\text{Total Budget } \$39,109}{\text{Total Structures } 258} = \$152/\text{structure}$

Table V

Total project costs (1983-84 combined) per unit structure type for habitat enhancement in Lolo Creek, Idaho.

Structure Type	Unit Cost
K-dam (complete)	$1250
K-dam (modified) reduced wing structure	$800
Log Weir	$370
Boulder Clusters (x 2.5 boulders/cluster)	$38 ($17/rock)
Large Individual Boulders	$16
Large Organic Debris	$52
Anchored Deflector Logs	$30
Boulder Weirs	$220
Boulder Deflectors	$130
Lateral Log Deflectors	$90
Bank Cover Devices (labor intensive)	$880
Debris Jam Removal (equipment intensive)	$826
Pool Construction	$10
Root Wads	$44

Avg. Total Project cost for all structures $= \frac{\text{Total Budget}}{\text{Total Structures}} = \frac{\$66,109}{392} = \$169$/structure

v. APPENDICES:

Appendix A	Map of structures requiring maintenance.

Appendix B	Distribution of felled large organic debris.

Appendix C	Classic (Wisconsin type) bank cover device. .

Appendix D	K-dam wing joint and crib reinforcement improvements.

Appendix E	1984 project map.

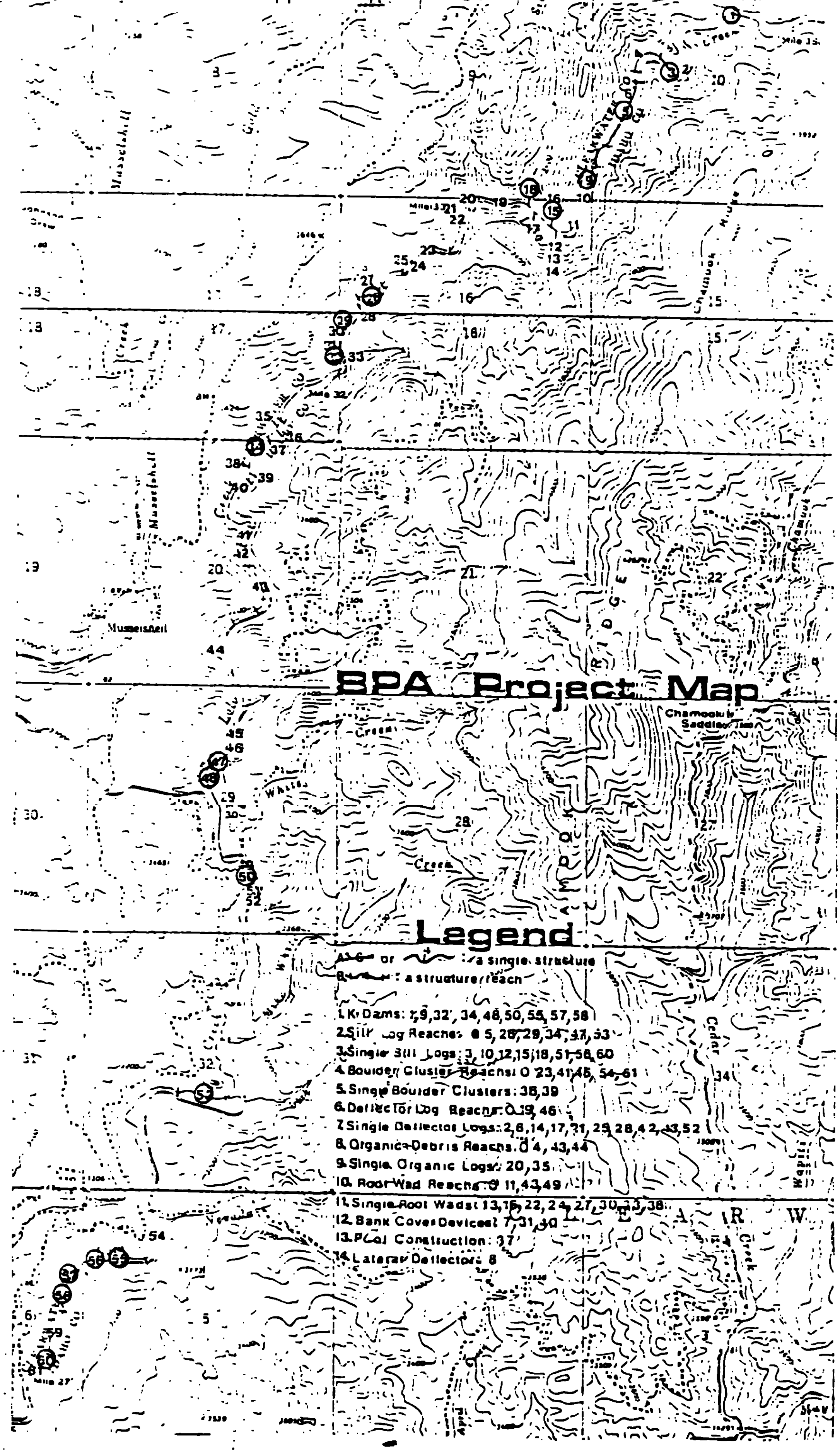
Appendix F	1983-1984 combined project map.

Appendix G	Explanation of yearly map totals and final map total (differences).

STRUCTURES REQUIRING MAINTENANCE

(23)

FIGURE-



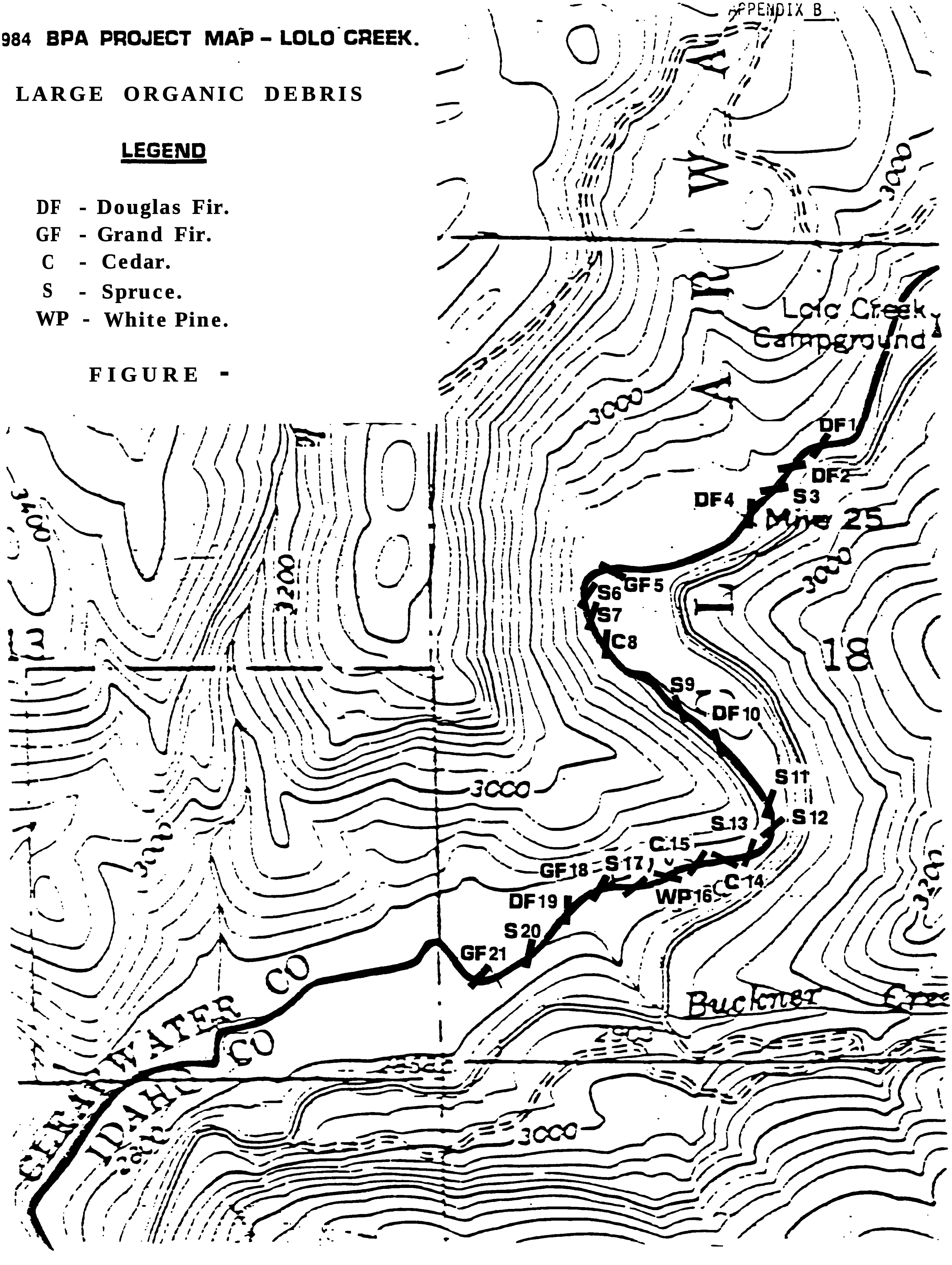
984 BPA PROJECT MAP - LOLO CREEK.

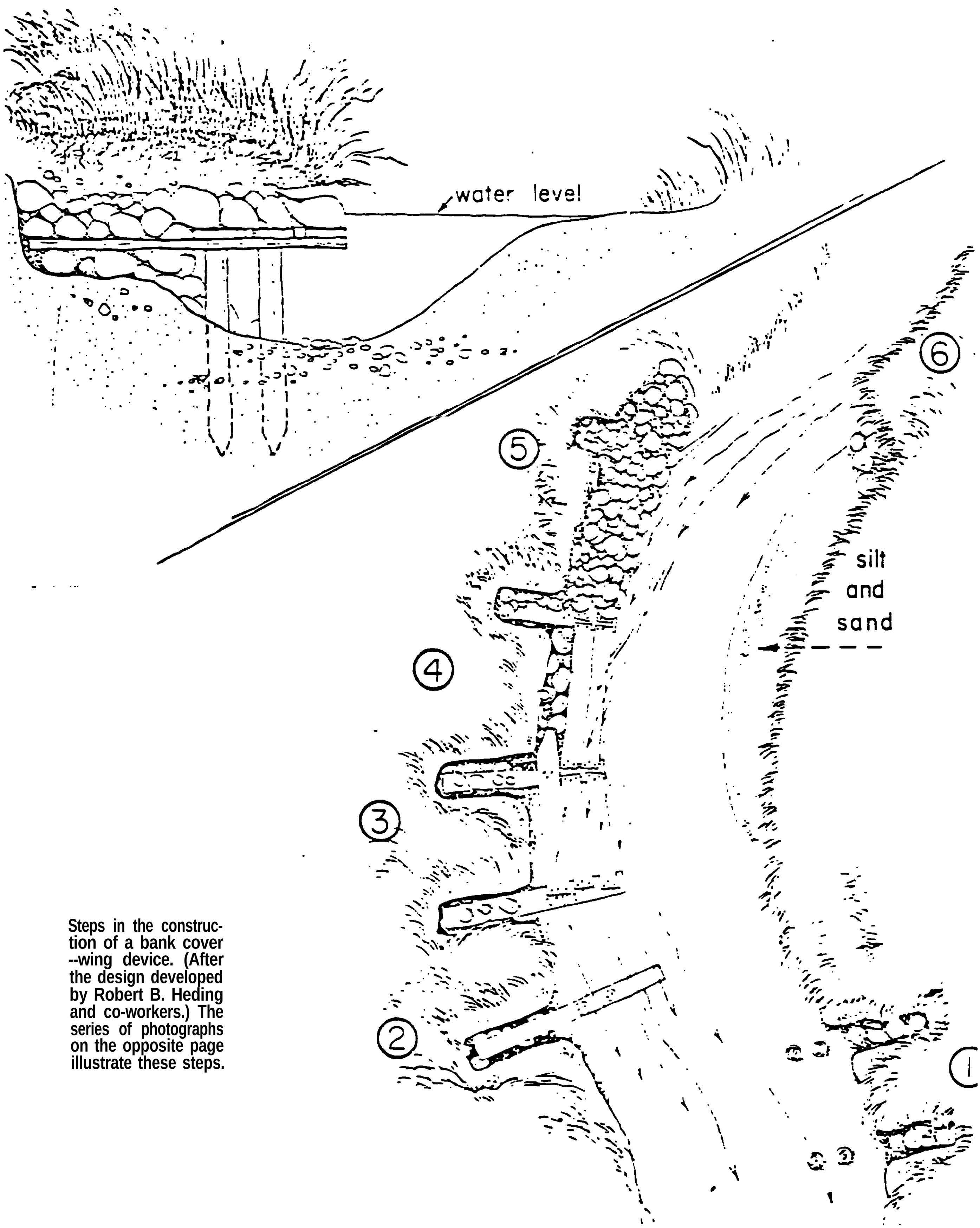
LARGE ORGANIC DEBRIS

LEGEND

DF - Douglas Fir.
GF - Grand Fir.
C - Cedar.
S - Spruce.
WP - White Pine.

FIGURE -





Steps in the construction of a bank cover --wing device. (After the design developed by Robert B. Heding and co-workers.) The series of photographs on the opposite page illustrate these steps.

APPENDIX D

K-dam Crib Reinforcement.

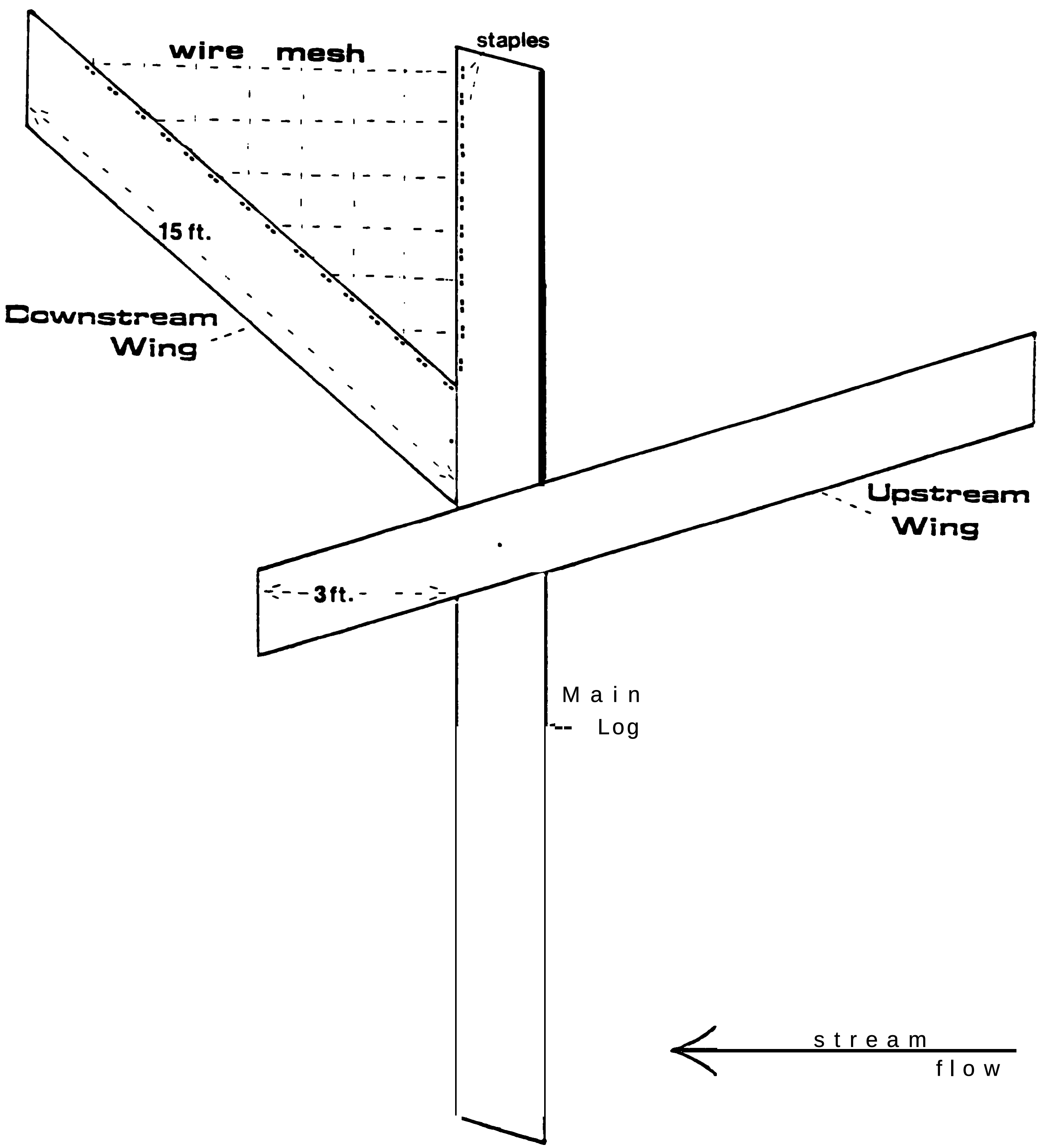


FIGURE -

K-Dam Wing Construction
Down Stream View

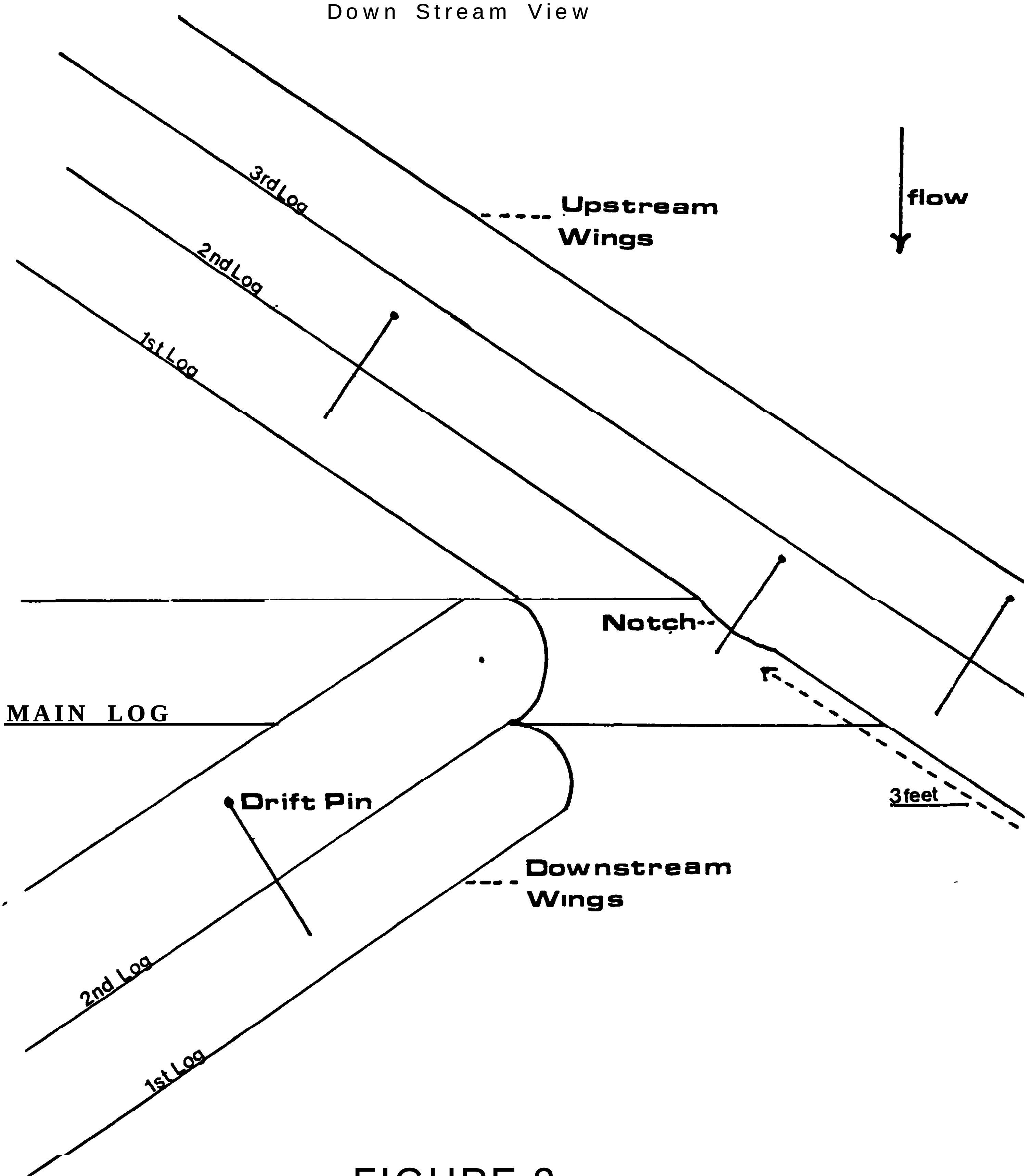
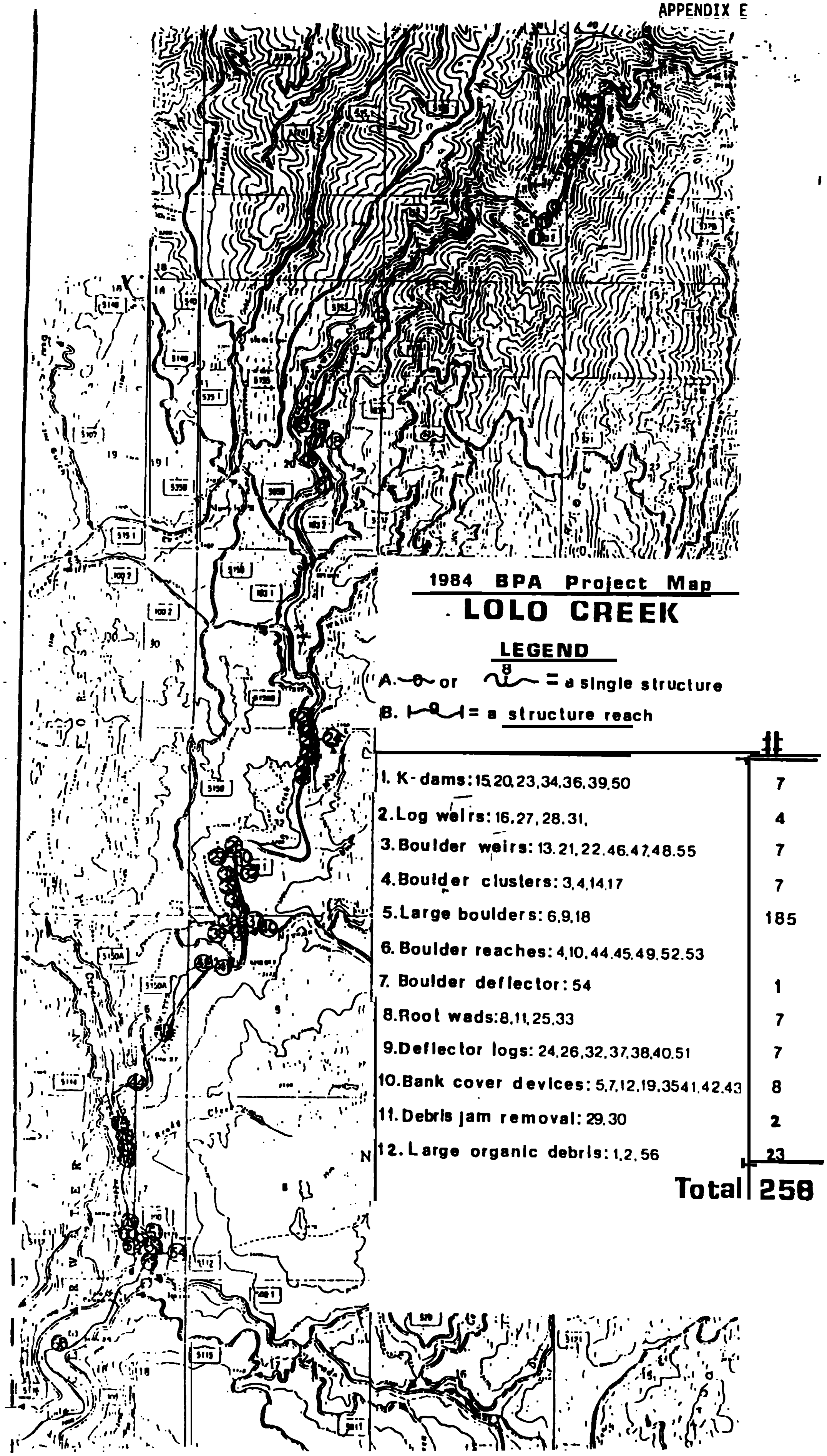
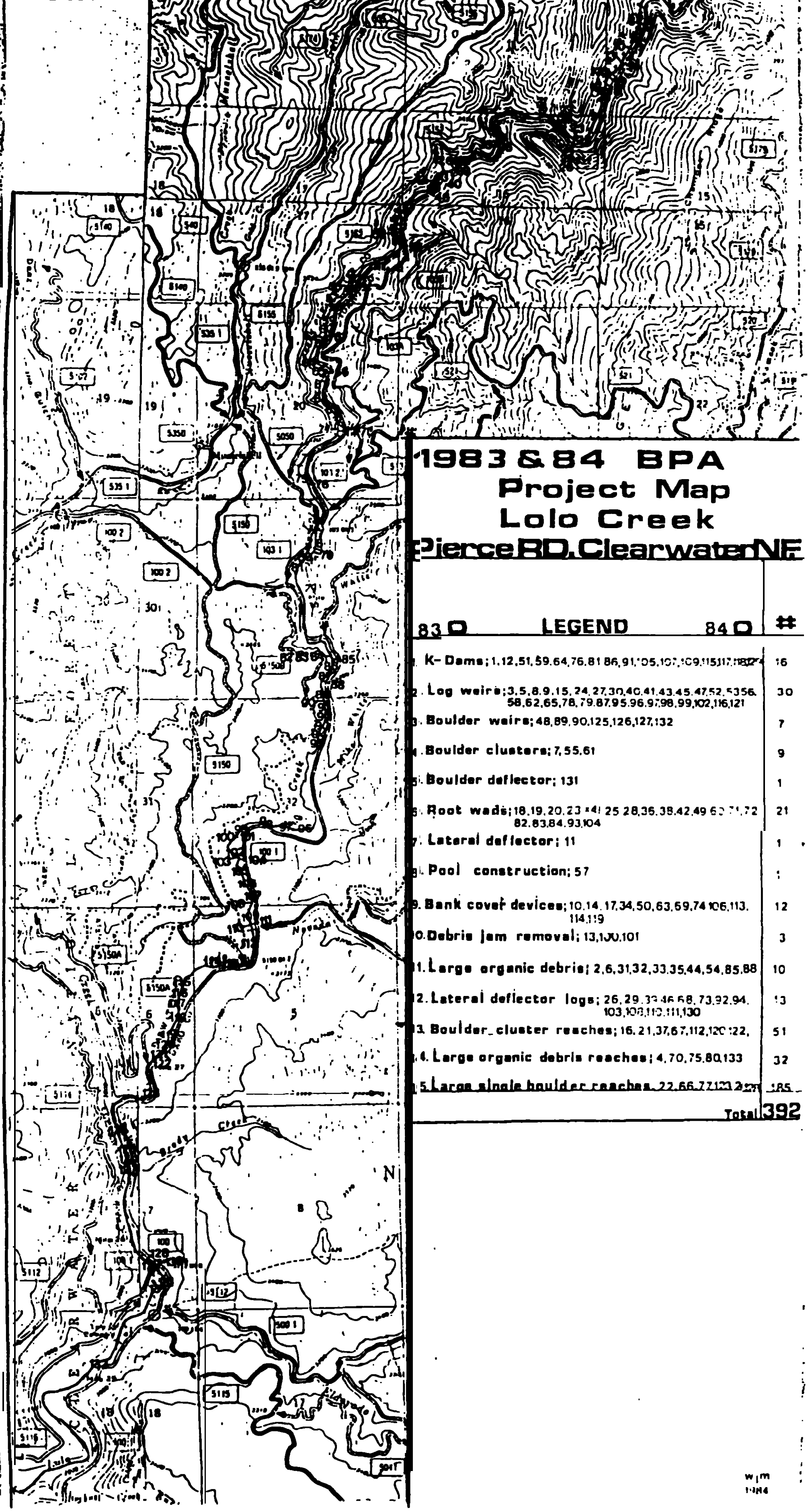


FIGURE-3


1984 BPA Project Map
LOLO CREEK
LEGEND
A. or = a single structure
B. = a structure reach
#
1. K-dams: 15,20,23,34,36,39,50 7
2. Log weirs: 16,27,28,31, 4
3. Boulder weirs: 13,21,22,46,47,48,55 7
4. Boulder clusters: 3,4,14,17 7
5. Large boulders: 6,9,18 185
6. Boulder reaches: 4,10,44,45,49,52,53
7. Boulder deflector: 54 1
8. Root wads: 8,11,25,33 7
9. Deflector logs: 24,26,32,37,38,40,51 7
10. Bank cover devices: 5,7,12,19,3541,42,43 8
11. Debris jam removal: 29,30 2
12. Large organic debris: 1,2,56 23
Total 258

APPENDIX F



1983 & 84 BPA
Project Map
Lolo Creek
Pierce RD. Clearwater NF
83
LEGEND
84
#
1. K- Dams; 1,12,51,59,64,76,81 86,91,105,107,109,115,117 16
2. Log weirs; 3,5,8,9,15,24,27,30,40,41,43,45,47,52,53,56, 58,62,65,78,79,87,95,96,97,98,99,102,116,121 30
3. Boulder weirs; 48,89,90,125,126,127,132 7
4. Boulder clusters; 7,55,61 9
5. Boulder deflector; 131 1
6. Root wads; 18,19,20,23 25 28,36,38,42,49 72 82,83,84,93,104 21
7. Lateral deflector; 11 1
8. Pool construction; 57
9. Bank cover devices; 10,14,17,34,50,63,69,74 106,113, 114,119 12
10. Debris jam removal; 13,100,101 3
11. Large organic debris; 2,6,31,32,33,35,44,54,85,88 10
12. Lateral deflector logs; 26,29, 68,73,92,94, 103,108,111,130
13. Boulder cluster reaches; 16,21,37,67,112,120 122, 51
14. Large organic debris reaches; 4,70,75,80,133 32
15. Large single boulder reaches 22,66,77,123 185
Total 392
N

Appendix G

Differences Between

Explanation of Yearly Map Totals and

Final Map Total

A. 1983 map shows 145 structures.

B. 1984 map shows 258 structures.

C. (145 + 258) = 403 structures.

D. Combined 1983-84 shows 392 structures or a difference of 11 structures.

E. **Reasons**:

1. We lost 2 root wads from 1 K-dam site hot cabled).

2. We removed 1 non-functioning log weir.

3. An error was noted on the 1984 map, structures #3 and #4 are the same (double count).

4. Debris jam removal 13 did not appear on 1983 map.

5. The remainder of the differences lies in the way the boulder reaches, boulder clusters, and large individual boulders were counted. We feel that after 2 years experience the 1983-84 combined method is the best way to count these structures.

Eldorado Creek Fish Passage

Annual Report

BY

Wally Murphy
District Biologist
Pierce Ranger District
Clearwater National Forest

Al. Espinosa Jr., Project Leader
Forest Fisheries Biologist
Clearwater National Forest

Funded By
The Bonneville Power Administration
Division of Fish and Wildlife

November 20, 1984

Modification M001 to Agreement
DE-A179-84BP16536
Project 84-6

TABLE OF CONTENTS

I. ACKNOWLEDGEMENTS:

We wouLd like to thank the following people for their hard work and professional guidance during this project.

Bob Vogelsang	-	Crew Leader
Bill Wells		Certified Blaster
Dr. John Orsborn	-	Fish Passage Consultant
Larry Everson	-	BPA Contracting Officer
Hudson Mann		Fisheries Technician

II. INTRODUCTION:

In 1984, and under the auspices of the Northwest Power Act, the Clearwater National Forest and the Bonneville Power Administration entered into a contractual agreement to improve anadromous fish habitat in two main tributaries to the Cleatwater River, in Idaho. The project was titled “Lolo Creek and Lochsa River Habitat Improvement,"Project Number 84-6 and Agreement Number DE-A179-4BP-16535. Effective July 1, 1984, the agreement was modified to include the “Eldorado Creek Fish Passage” project, modification number M001. Total funding for the project was $17,668. The project called for modifying 4 rock fails barriers to allow anadromous fish passage during both high and low flows.

The following report is a description of the project objectives, methodologies, baseline conditions, activities, results, and conclusions.

A. Project Objectives:

The primary objective of the project was to partially mitigate the juvenile and adult anadromous fish losses accrued through hydroelectric development in the Columbia and Snake River by enhancing or making available the spawning and rearing habitats of selected Cleat-water River tributaries for spring chinook salmon and steelhead trout. The removal of fish passage barriers was designed to make available historic spawning and rearing habitats and reestablish historic runs of anadromous fish.

Eldorado Creek Objectives:

1. Modify the 4 existing barriers to anadromous fish migration so that unimpeded fish passage will be possible during both high and low flows.

2. Make available 2 acres of spawning and 40 to 50 acres of rearing habitats to spring chinook salmon and summer steelhead trout.

3. Reestablish the historic run of anadromous fish in Eldorado Creek.

B. Description of Project Area:

Eldorado Creek

Eldorado Creek is a 6th order tributary of Lolo Creek, flowing northwest for 18 miles, draining a total of 48 square miles. Average width, depth, and gradient are respectively 29.7 feet, 1.5 feet, and 1.4 percent. The pool/riffle ratio averages 15:85. Cobble embeddedness averages 50 percent over the system. Elevation in the watershed ranges from 5,480 feet So 2,850 feet. Presently the system provides approximately 2 acres of anadromous fish rearing habitat. Major tributaries to Eldorado Creek include; Trout, Fan, Lunch, Q-Bit, 6-Bit, Austin, Dollar, and Cedar Creeks.

For a complete description of the Clearwater National Forest and the Lolo Creek system, refer to the 1983 Annual BPA Project Report - The Lolo Creek and Upper Lochsa Habitat Enhancement Projects - #83-522, by Al Espinoza, Jr.

Barrier Sites

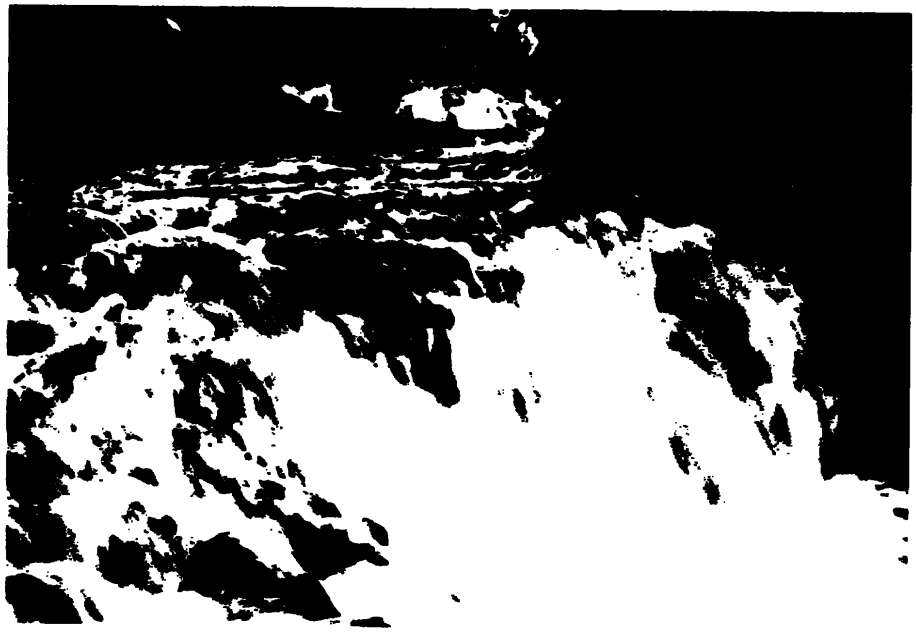
Four barriers to anadromous fish migration have been identified in lower Eldorado Creek. All 4 of the sites occurred within a l/4 mile reach with the lower site located l/2 mile from the mouth of Eldorado Creek. With minor exception for some extraordinary steelhead, the barriers completely prohibit salmon and steelhead from reaching upstream habitats.

Site Number 1 the first migration barrier, proceeding upstream from the mouth of Eldorado Creek, was formed by a large basalt sheet. This sheet covered the entire width of the stream and was approximately 86 feet long. A crest at the upstream end spreads the water over the basalt sheet for approximately 60 feet, at an average gradient of 8 percent. The last 20 feet was a steep drop (40 percent gradient) to the toe of the basalt sheet. Please refer to the Project Area Map for location and Figures 1 through 5 for photographs of the barrier.

Site Number 2 was formed by two large basalt outcrops which pinched the channel to the right bank, looking upstream; refer to Figure 7, a photograph of the barrier. The upper basalt outcrop forced 90 percent of the water to the right bank where it fell 5 feet over a high velocity falls to a pool at the apex of the second basalt outcrop. The second outcrop forced the water into a high velocity trough some three feet wide and 20 feet long with a gradient of 15 percent. The end of the trough was approximately 75 feet from the crest of Site Number 1, refer to Project Area Map for location of Site Number 2.

Site Number 3 is known as Eldorado Falls. Here the water falls for 28 feet at a 35 percent gradient. The fails occupies the entire width of the channel, refer to Figures 8 through 12. A large plunge pool, 25 feet wide and 45 feet long, was created by the falls. The water leaves the plunge pool at right angles to the falls, from the right side facing upstream.

Figures 1 and 2: Upper and Lower photos show barrier #1 prior to treatment.



Figures 3 and 4: Upper and Lower photos show barrier #1 prior to treatment.

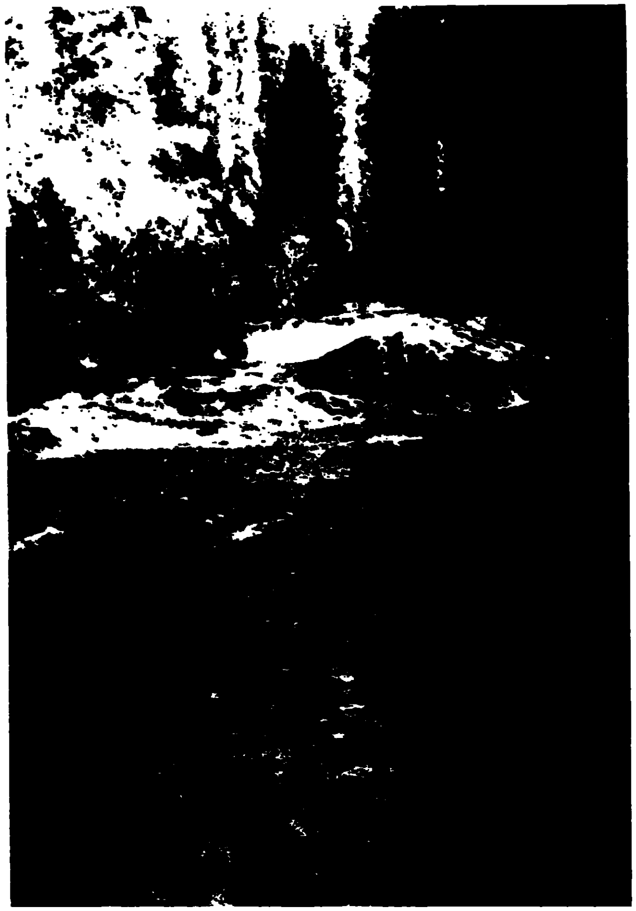
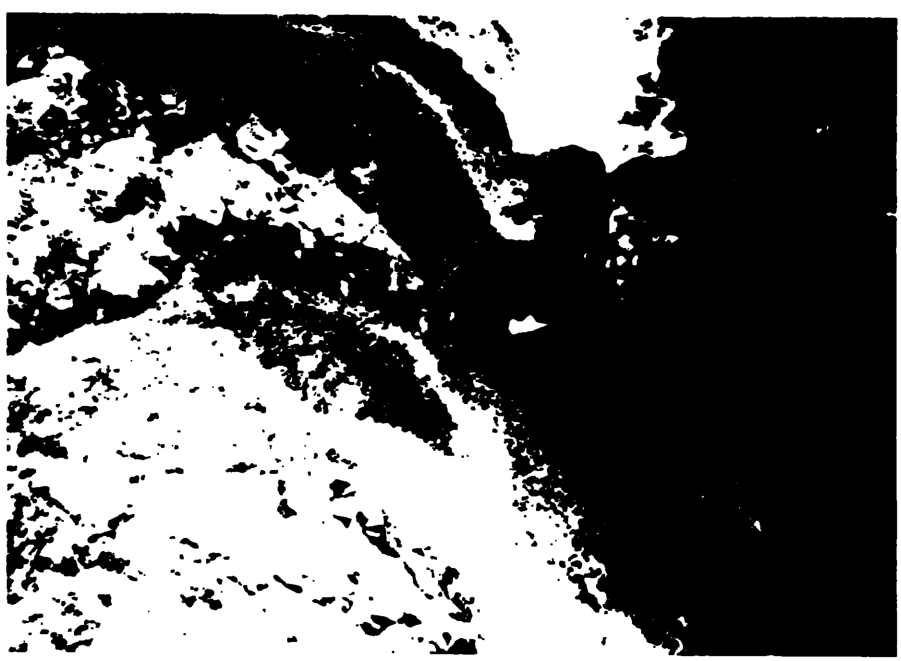


Figure 5: Photo shows barrier #1 prior to treatment.

Figures 6 and 7: Upper and Lower photos show barrier #2 prior to treatment.



Figures 8 and 9: Upper and Lower photos show Eldorado falls, barrier #3 prior to treatment.

Figures 10 and 11: Upper and Lower photo show Eldorado Falls, barrier #3 prior to treatment.

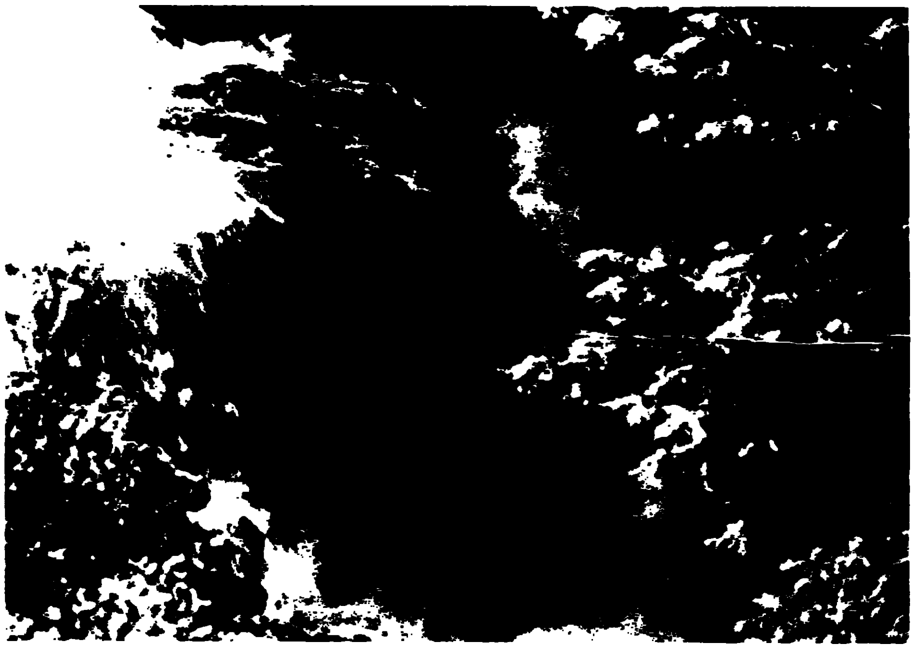


Figure 12: Photo shows Eldorado Falls barrier #3 prior to treatment.

Powers (1984) discussed the geometry of this barrier, in his study of new methods for migration barriers. Figure 1, page 5 in Appendix C, shows the leaping capability of steelhead trout in relation to the falls profile. He postulated that only under the best conditions would spawning steelhead be able to execute a successful jump. Refer to Appendix B for location of Site Number 3.

Site Number 4 was formed during the construction of Clearwater Forest road number 500, the Lolo Motorway/Lewis and Clark Trail. Rip-rap fill for support of the road bed blocked the channel. The result was a dispersal of water and a 12 foot vertical barrier with no pool at the bottom, refer to Figures 13 and 14. Two large rocks formed a ‘V’ through which the largest volume of water fell and splashed on more rip-rap. This site was the only change from the days when Lewis and Clark observed spawning steelhead in the upper reaches near Dollar Creek. This migration barrier was created in the mid-1950's, refer to Figures 13 and 14. The rip-rap extends from the creek bottom 50 feet up to the road bed at a gradient of approximately 80 percent. This barrier was the most critical of the series as it stopped salmon and steelhead from upstream passage at all flow regimes.

III. METHODS AND MATERIALS:

With the identification of the 4 migration barriers completed, the first step was to analyze the barriers and formulate a plan for treatment. To accomplish this, we hired Dr. John F. Orsborn, a Hydraulic Engineer and a Fish Passage Consultant from Washington State University at Pullman. A copy of his analysis and plan is presented in Appendix C. Essentially, Dr. Orsborn recommended blasting a series of pools with sills to allow for passage at both high and low flows for ail four barriers (Appendix C).

Pre-Implementation Phase

On September 1, 1984, we began organizing the project. A certified blaster, Bill Wells, was borrowed from the Kelly Creek District. We also borrowed a Pionjar rock drill and bits, along with several cases of dynamite (60%), blasting caps, primer cord and a blasting box. A Calvanometer was used to check the continuity of the electric lines. Channel profiles were run on barriers 1, 2, and 3.

The next step involved the briefing of the crew on the plan and necessary safety measures. Safety was especially important since we were working along the 500 road.

Implementation Phase

On September 4, 1984, we began treatment of barrier #4. The design pool was measured and using the Pionjar drill, numerous holes were drilled for each pool, the charges were set and blasted individually. This allowed an evaluation of the results prior to blasting the next pool. Drilling and blasting the granite rip-rap at Site #4 took one day.

Figures 13 and 14 : Upper and Lower photos show barrier #4 prior to treatment.

On September 5, we began working on Site #3, Eldorado Falls. We soon learned that drilling and blasting in basalt was quite different from granite. The existing layers separated by fractures, caused the drill to stick, and pools larger than measured were blasted. The fractured rock also absorbed the shock so that the blasted materials remained in the pool. This material had to be removed by hand. The same problems were encountered while drilling and blasting Sites #l and #2. Due to the steep gradient of the face of Eldorado Fails, it was impossible to stand on the falls and drill the holes, even when tied-off to a tree on the bank. Figures 15 through 20 show the crew working on the barriers. On Spetember 14, 1984, the last pool was blasted at Site #l. We spent 1 week cleaning the fractured rock from the blasted pools.

Upon cleaning the pools, it became obvious that some pool depths were not adequate at all the sites. To remedy this, rock berms were constructed to raise the water level in the pools. Rock berms were constructed at the following pools: Site #1; pools B, C, and D,: Site #; pools B and C: Site #3 ; pool B: and Site #4; pools B and C. Refer to Appendix D through C.

IV. RESULTS AND DISCUSSION:

Sites Number 1, 2, and 4, were treated according to Dr. Orsborn's plan. Site Number 3 was not, due to the difficulty encountered in drilling on the face of the falls.

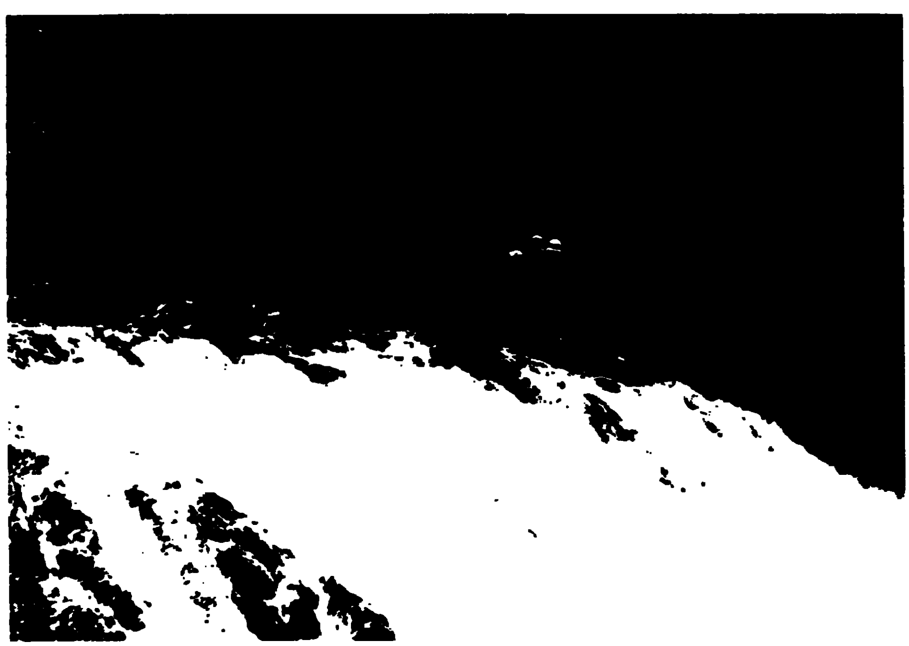
Four pools were created at Site Number 1. Pool parameters are shown in Appendix H, along with a schematic drawing of the results at Site Number 1, in Appendix D. Mean depth, length, width, rock berms and juxtaposition are shown. Refer to Figures 21 and 22, photographs of the results.

Four pools (A, B, C, and E) were created at Site Number 2. Pool D already existed (Appendix E). Appendix E presents a schematic drawing of the juxta position of the pools to each other and their arrangement in the barrier, along with several pool parameters. A complete list of pool parameters is presented in Appendix H. Figures 23 and 26 show the results at Site Number 2.

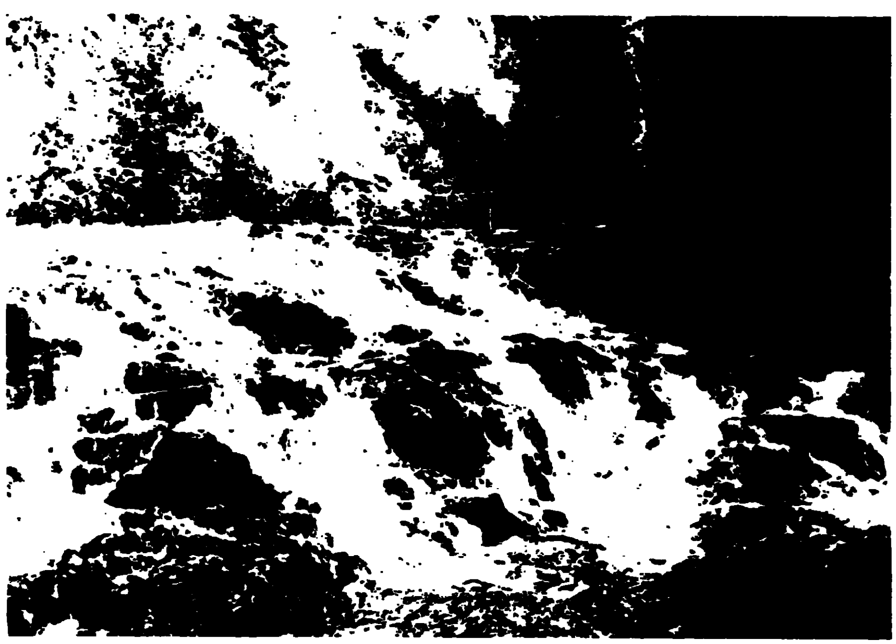
Dr. Orsborn's plan called for creating 3 pools at Site Number 3, Eldorado Fails, and enhancing a fourth one. We created one pool at the site and enhanced the other. The steepness of the face of the falls prevented our creating more pools here. Appendix F shows a schematic drawing of the results at Site Number 3 along with several pool paramters. A complete list of pool parameters is presented in Appendix H. Figures 27 through 30 show the results at Site Number 3.

Blasting of Site Number 4 was the most successful. The 12 foot wall was destroyed and 3 pools were created in its place. Appendix G shows a schematic drawing of the results along with several pool parameters. A compete list of pool parameters is presented in Appendix H. Figures 31 through 34 show the results at Site Number 4.

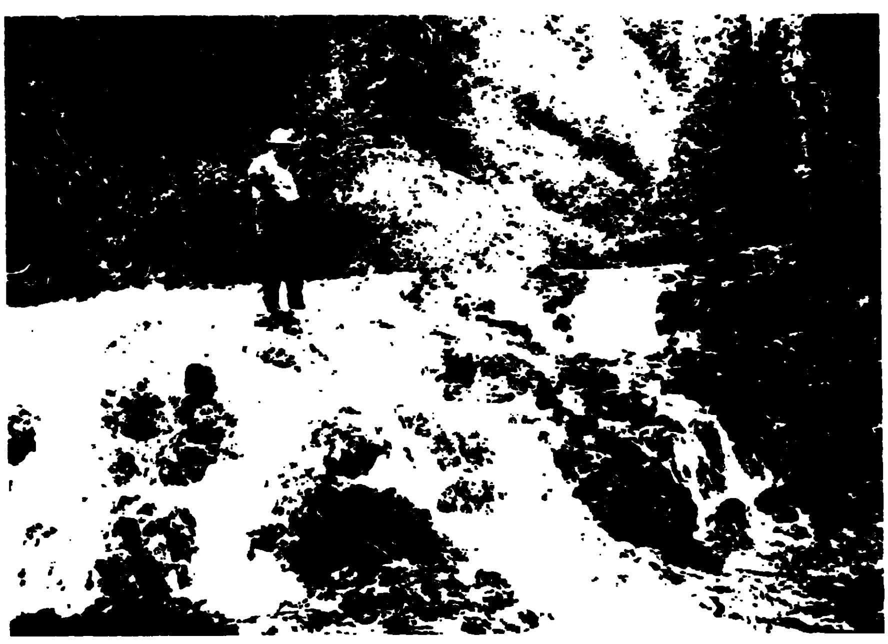
Figures 15 and 16: Upper and Lower photos show crew working at barrier #3, Eldorado Falls.



Figures 17 and 18: Upper photo shows blaster Bill Wells with holes drilled and primer cord in hand. Lower photo primer cord strung out with charges set.



Figures 19 and 20: Upper photo shows crewman pitching basalt rocks from blasted pool. Lower photo shows Bill Wells and recently blasted pool at barrier #1.



V. SUMMARY AND RECOMMENDATIONS:

Corrective actions taken in 1984 at 4 rock barriers in Eldorado Creek have facilitated upstream passage of chinook salmon and steelhead trout. Barrier Number 4 is considered essentially corrected and will require no further work with explosives. Some pool berms at Site Number 4 may require additional reinforcement with larger substrate materiaLs. This site will be evaluated after spring run-off. If additional work is needed, heavy equipment will be contracted to complete the job.

TABLE I
Specific Areas Needing Further Work in 1985

Site Number 1:

1. Pool A - Increase depth and reduce drop
2. Pool B - Increase length and depth
3. Pooi C - Adequate
4. Pool D - Increase length and depth

Site Number 2:

1. Pool A - Increase width, depth and drop
2. Pool B - Increase depth
3. Pool C - Increase depth
4. Pool D - Increase width
5. Pool E - Increase width

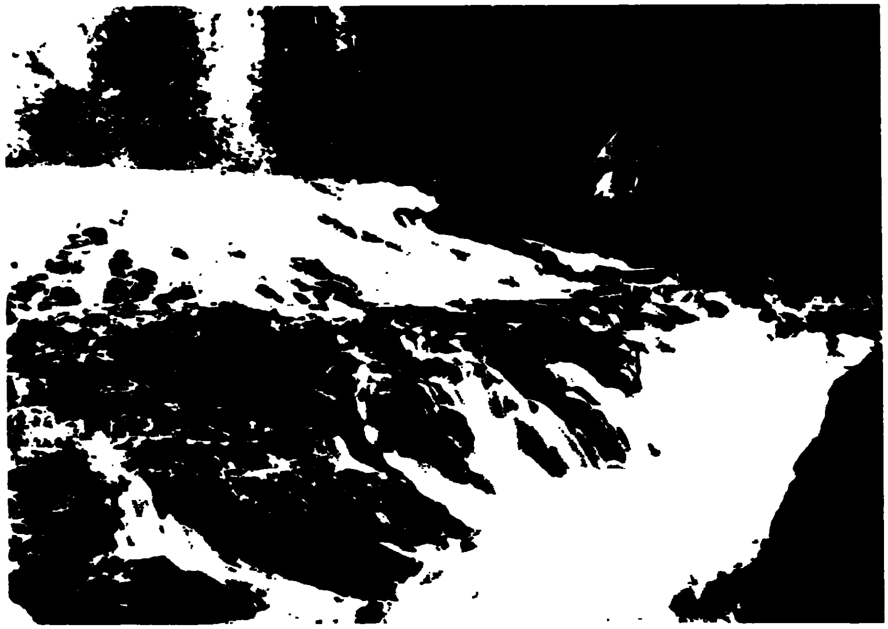
Site Number 3:

1. Pool A - Increase depth and lessen drop
2. Pool B - Construct
3. Pool C - Optional construction
4. Pool D - Adequate

Site Number 4: Correction of pool berms (pl acement of larger substrate materials).

Barrier Numbers 2 and 3 are considered partially corrected. Total correction will involve enhancement of the pools created in 1984 (Table I), to comply with design standards (Appendix C).

Corrective actions at Site Number 3 are considered incomplete. Those taken In 1983, were successful (Table I). However, to totally correct this barrier, 1 or 2 pools will be required aiong with elimination of the splash rock (Appendix C).

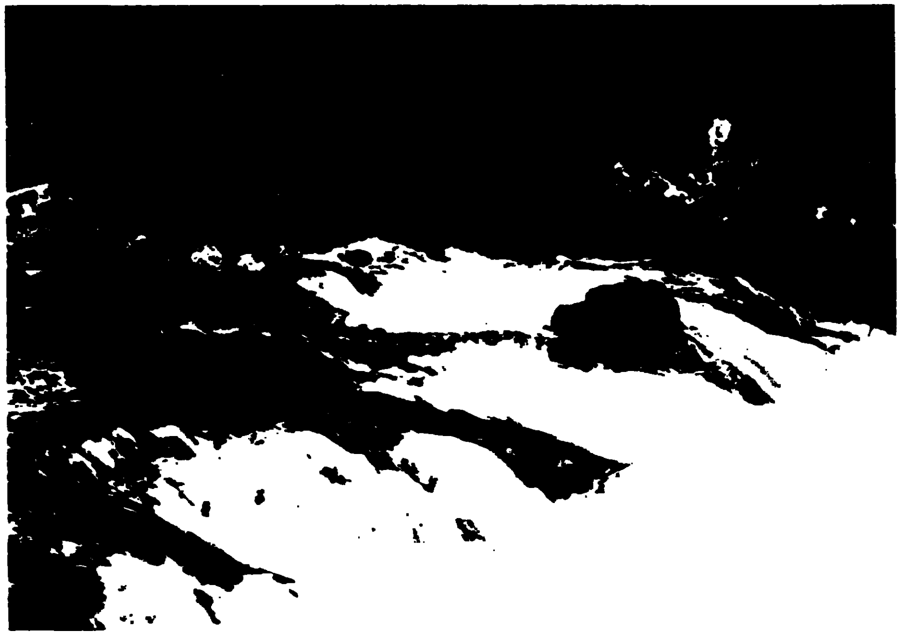


Figures 21 and 22: Upper and Lower photos show the pools created at barrier #1.

Figures 23 and 24: Upper and Lower photos show pools created at barrier #3.

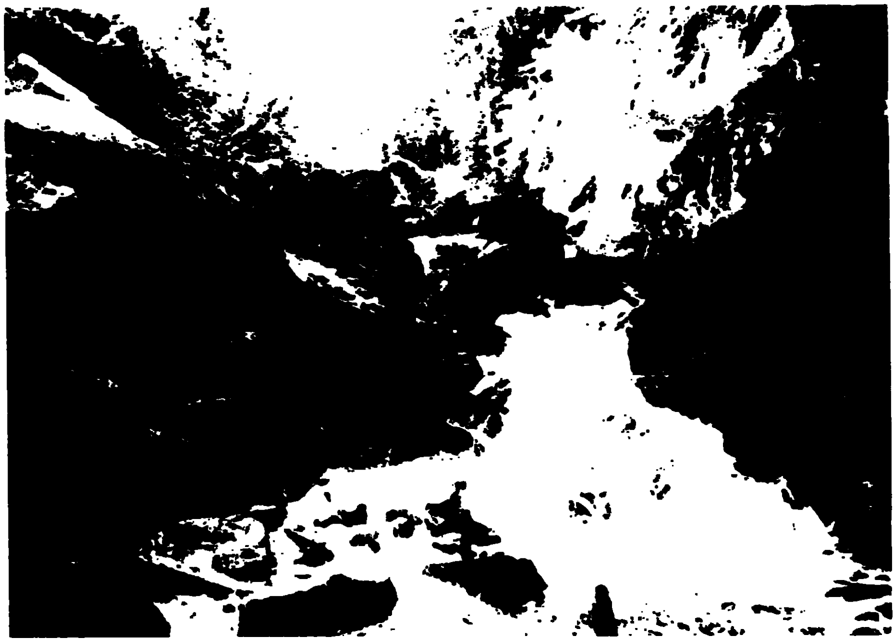
Figures 25 aand 26: Upper and lower photos show pools created at barrier #3.

Figures 27 and 28: Upper photo shows entire falls with rock berms and pool. Lower photo shows upper and lower pools. Note steep face of Eldorado Falls, barrier #3.



Figures 29 and 30: Upper photo shows upper pool and rock berm. Lower photo shows lower pool and rock weir. Note rock weir already starting to catch debris.

Figures 31 and 32: U'pper and lower photos shows the resui ts at barrier #4.



Figures 33 and 34: Jpper and lower photos show the results at barrier #4.

VI. APPENDICES:

A. Vicinity Map

B. Project Area Map

C. Report by Fish Passage Consuitant, Dr. J. R. Orsborn

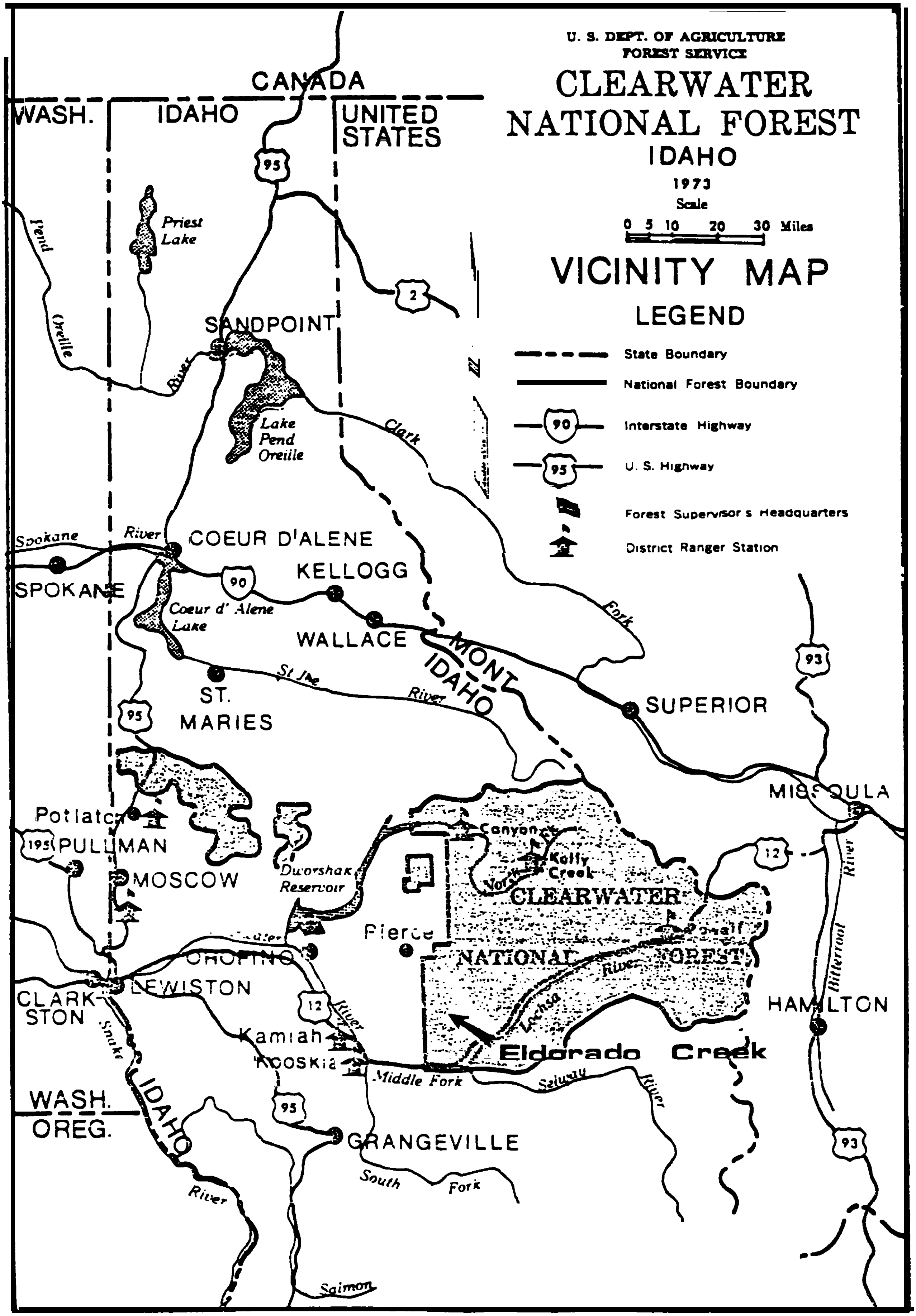
D. Schematic of Site Number 1

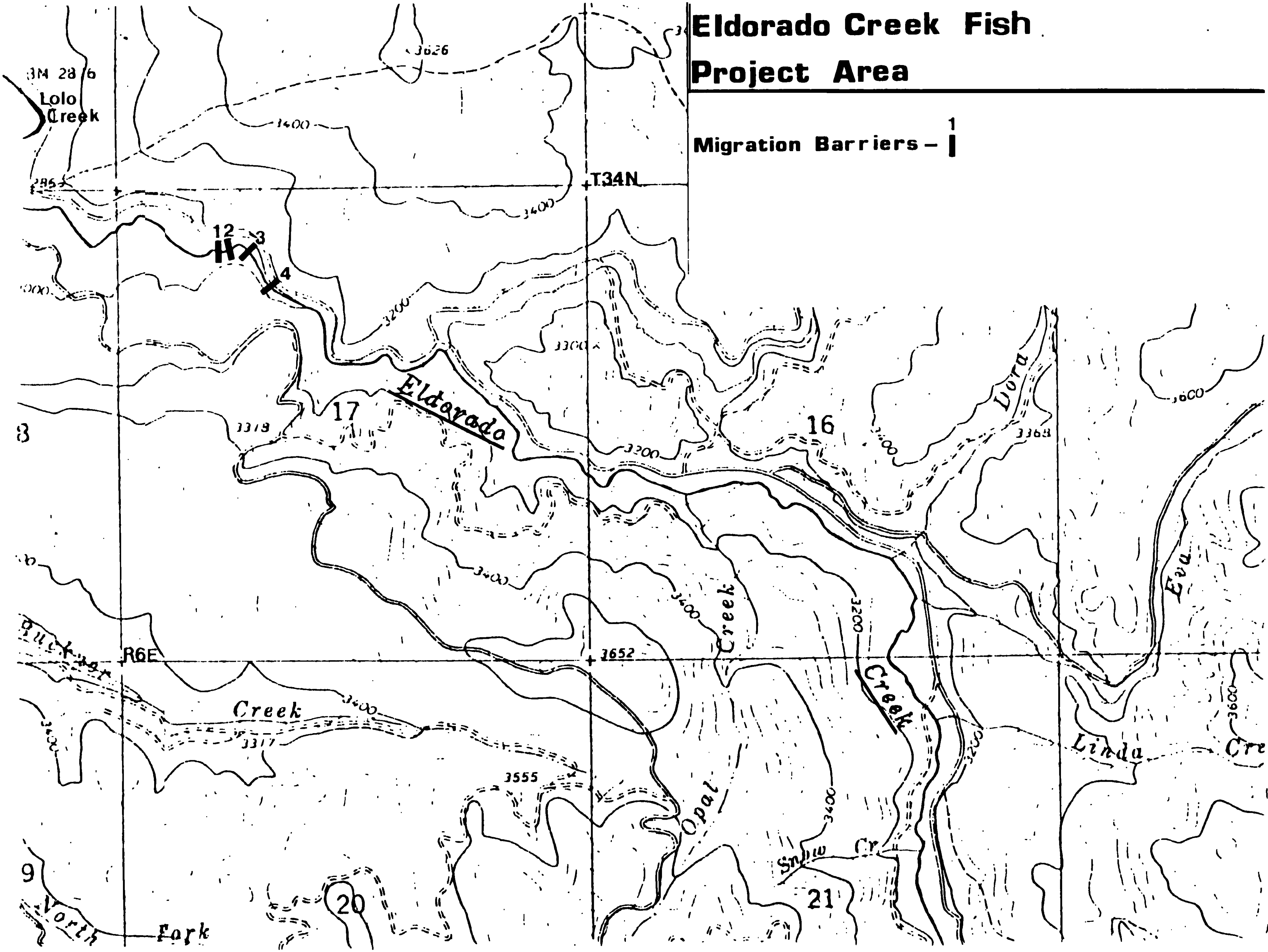
E. Schematic of Site Number 2

F. Schematic of Site Number 3

G. Schematic of Site Number 4

H. Pool Parameters


U. S. DEPT. OF AGRICULTURE
FOREST SERVICE
CLEARWATER
NATIONAL FOREST
IDAHO
1973
Scale
0 5 10 20 30 Miles
VICINITY MAP
LEGEND
State Boundary
National Forest Boundary
Interstate Highway
U. S. Highway
Forest Supervisor's Headquarters
District Ranger Station
CANADA
WASH.
IDAHO
UNITED STATES
Priest Lake
Pend Oreille River
SANDPOINT
Lake Pend Oreille
Clark Fork
Spokane River
COEUR D'ALENE
SPOKANE
KELLOGG
WALLACE
Coeur d' Alene Lake
St Joe River
ST. MARIES
MONT
IDAHO
SUPERIOR
MISSOULA
Potlatch
PULLMAN
MOSCOW
Dworshak Reservoir
Canyon
Kelly Creek
North Fork
CLEARWATER
NATIONAL FOREST
Powell
Pierce
OROFINO
LEWISTON
CLARKSTON
Lochsa River
Eldorado Creek
Bitterroot River
HAMILTON
Kamiah
Kooskia
Middle Fork
Selway River
Snake River
WASH.
OREG.
IDAHO
GRANGEVILLE
South Fork
Salmon



Eldorado Creek Fish
Project Area
Migration Barriers – 1
Lolo Creek
3626
1400
T34N
3400
1 2
3
4
3200
3300
17
8
Eldorado
3319
16
Dora
3368
3600
3400
Creek
Eva
3200
R6E
3652
Creek
Creek
Linda
Cre
3555
Opal
3317
Snow Cr
9
20
21
North Fork

Report on

CORRECTION OF FISH PASSAGE BARRIERS ON ELDORADO CREEK AND CROOKED FORK

—

CLEARWATER NATL. FOREST

—

Prepared for

AL ESPINOSA, Project Leader
12730 HIGHWAY 12
OROFINO, ID 83544

Prepared by

JOHN F. ORSBORN, P.E.
NW 420 MARYLAND CT.
PULLMAN, WA 99163

Work Conducted Under

PURCHASE ORDER No.
43-0276-4-0361 (6/4/84)

AUGUST 7, 1984

PART 1. FOUR BARRIERS ON ELDORADO CREEK -;

PART 2. BARRIERS ON CROOKED FORK OF THE LOCHSA RIVER NEAR POWELL, IDAHO.
(TO BE SUBMITTED SOON)
DESIGNS PROVIDED IN THE FIELD 8/1/84.

INTRODUCTION

Fish passage sites were inspected during a field trip on July 31 and August 1, 1984. The barriers to upstream migration are located on:

(1) Eldorado Creek, a tributary of Lolo Creek, Northeast of Kooskia, ID; and

(2) Crooked Fork, a tributary of the Lochsa River, with the sites being located Northeast of Powell Ranger Station.

INFORMATION PROVIDED

(1) Eldorado Creek:
- (a) BPA Project proposal with general project description, location maps, and ER;
- (b) Nine flow measurements in 1979-1980 from the STORET file; and
- (c) Two photographs of the uppermost barrier site, out of four barriers.

(2) Crooked Fork of the Lochsa River:
- (a) a photograph of each of the seven (7) barriers;
- (b) A location map of the seven barriers;
- (c) Seasonal flow analysis of Crooked Fork flows when Steelhead (April-May) and Chinook (July-September) are migrating; and
- (d) An aerial photograph of the site vicinity.

ANALYSIS OF BARRIERS

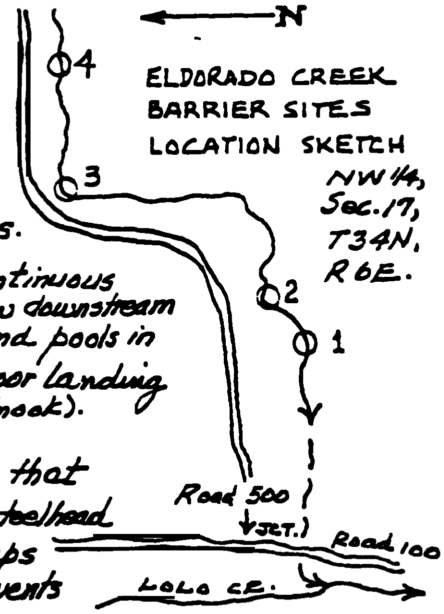
ELDORADO CREEK

The barriers consist of a pair of basalt rock aprons, the upper most of which has a series of vertical drops as large as 4 ft, during low flows. The locations of the four (4) sites are shown in the sketch on the next page and are numbered in an upstream direction for cataloging.

BARRIER SITE DESCRIPTIONS

NO.	FEATURES
1	Basalt flow with flow along outside, curved left* bank and over a hump on the right. Shallow depth and high velocities.
2	Just upstream of Site 1 and continuous with No. 1. Shallow sheet flow downstream part with several low drops and pools in upper part. Shallow depth, poor landing pool(s) at lower flows (Chinook).
3	A high velocity, shallow chute that drops 7-8' in about 14'. Some steelhead can make passage if their leaps are optimal. Shallow depth prevents Chinook passage.
4	A 7-8' falls complicated with large road rock which has narrowed the passage. Bedrock beneath shallow downstream pool prevents leaping during low flow, as does rock at crest of fall.

*Note: Stream flow convention denotes left and right when looking downstream. This is the reverse of the direction of fish migration.

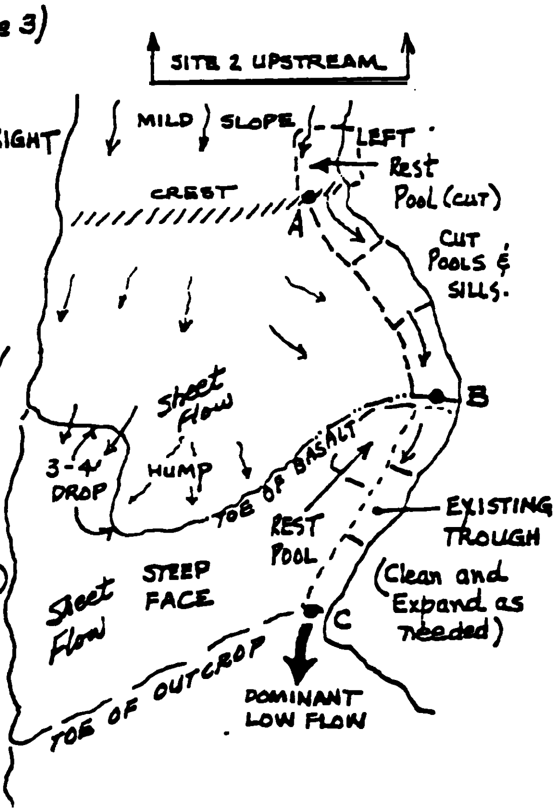


SUGGESTED CORRECTIONS

SITE NO. 1 (Details on page 3)

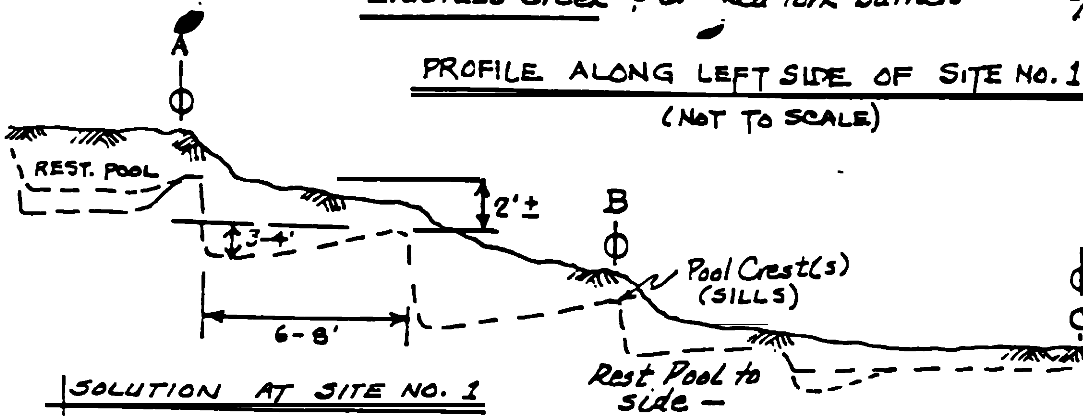
Could blast a series of three pools down the right side, but Chinook attraction flow is down the left side. Therefore, with less blasting, a series of smaller pools and drops can be constructed down the upper part from the crest (A) to the existing trough (B). The trough should be cleaned and pools with sills created as needed to (C).

Two (min). resting pools should be cut out of the main basalt flow beside the passage channel and pools.



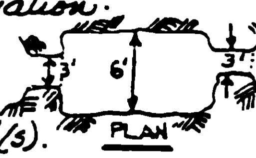
PROFILE ALONG LEFT SIDE OF SITE No. 1

(NOT TO SCALE)

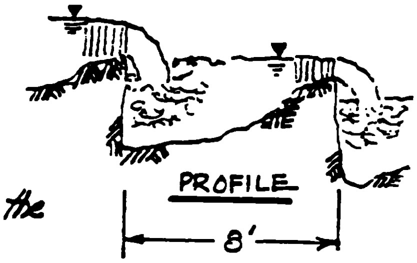


SOLUTION AT SITE NO. 1

- Survey the left bank profile along the flow path.
- Plot the profile and then plot pools 6-8' long (preferably 8') about 3-4' deeper in the upstream end than the outlet crest (SILL) elevation.
- Pools should be about 6' wide ±.
- Notches for flow over sills should be about 3'± wide and slope up to the sill(s).



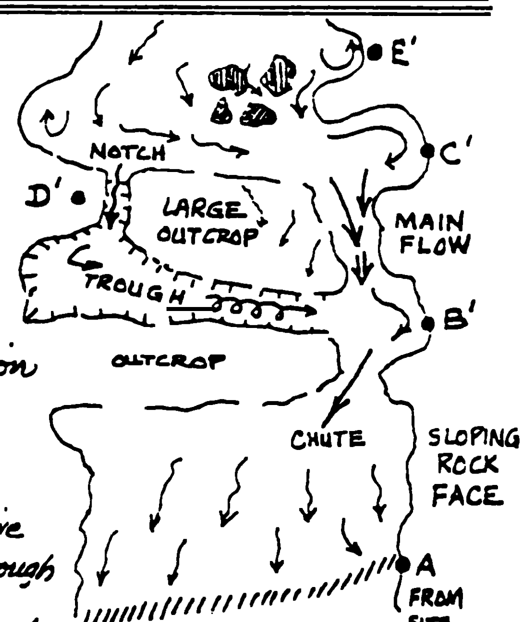
- Drop in elevation between sills should be about 2' and fall faces should be cleaned vertically to avoid distracting splashes.



- Fit the lowest pool near (B) into the existing trough.
- Modify the trough (as needed) to create good passage with a couple of pools & sills. (may need 1-2 steps).
- By deepeing the channel towards the upstream end the fish should be able to swim to the first resting pool near (B).

SITE NO. 2

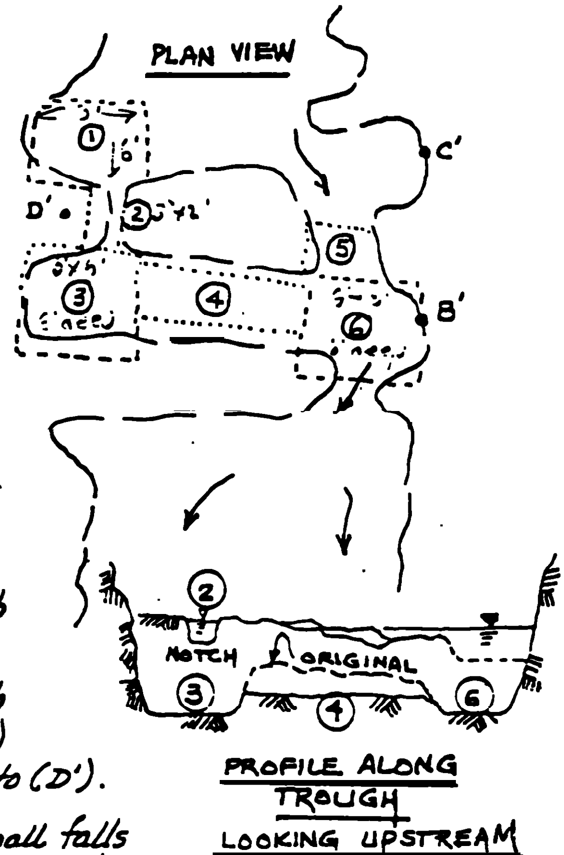
IF: fish can make it to (A) at the upper end of SITE No. 1, they can probably make it to the small pool at (B'). Here the main flow over a 3-4' falls joins with flow down a trough from the notch at D'. Negotiation from B' to C' would require deepening and enlarging the pools at B' and C'. Poor leaping conditions exist at B'. An alternative would be to clean and enlarge the trough from B' to D', enlarge the pool below D' and the notch and upstream pool.



SKETCH OF SITE NO. 2 - PLAN -

SOLUTIONS AT SITE No. 2

Suggested excavations by blasting are shown by dotted (····) lines in sketch at right.



(1) Excavate resting pool upstream of notch by (D'). 4' Deep, by 8' long (across flow) by 6' wide (in direction of flow)

(2) Excavate slot 3' wide and 2' deep with floor sloping up towards sill where flow drops in to pool (3).

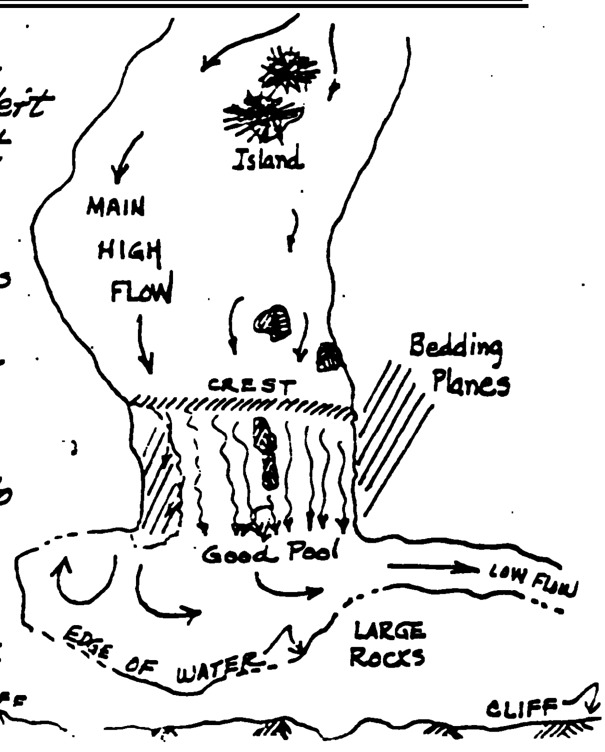
(3) Excavate pool about 6-8' square and 6' deep for plunge pool for flow through notch No. 2.

(4) Clean out and deepen trough (especially at upstream end) for fish passage from (B') to (D').

(5) IF POSSIBLE, Make face of small falls more vertical and clean off any splash rocks.

(6) Enlarge and deepen pool - will make it easier for fish to either leap to pool beside (C') or swim up trough (4) and leap to pool (1) through notch (2). Make Pool 6 about 8'x8' and 6' deep.

SITE No. 3 High velocity chute just upstream of 90° bend to left in Eldorado Creek. Small, but deep pool constricted by large rocks in deposition area at base of basalt cliff. High flows pass around large rocks along base of cliff as well as down low flow channel to the left. Bedding plans in chute rock and shore diagonal down to the right. A splash rock at the base of the chute (just left of center) may disorient leaping. Solutions are discussed on page 5.



Powers[1] recently discussed the profile geometry of this Eldorado Creek barrier in his study of new methods for migration barrier analysis. Fig. 1 shows the profile with leaping curves for steelhead in different condition (nearness to being ripe). The "Condition of the fish" (Cfc) or coefficient of fish condition is related to an estimate of their capability to swim burst, prolonged and sustained speeds as related to the distance they have traveled from the ocean (nearness to spawning site), and the time to spawning. The two sets of curves, based on projectile body mechanics show that probably only the strongest steelhead (Cfc = 1.00) leaping at 60° would land near the crest and execute a successful passage. Some might be able to swim the last few feet if the discharge was large enough to provide adequate body depth.

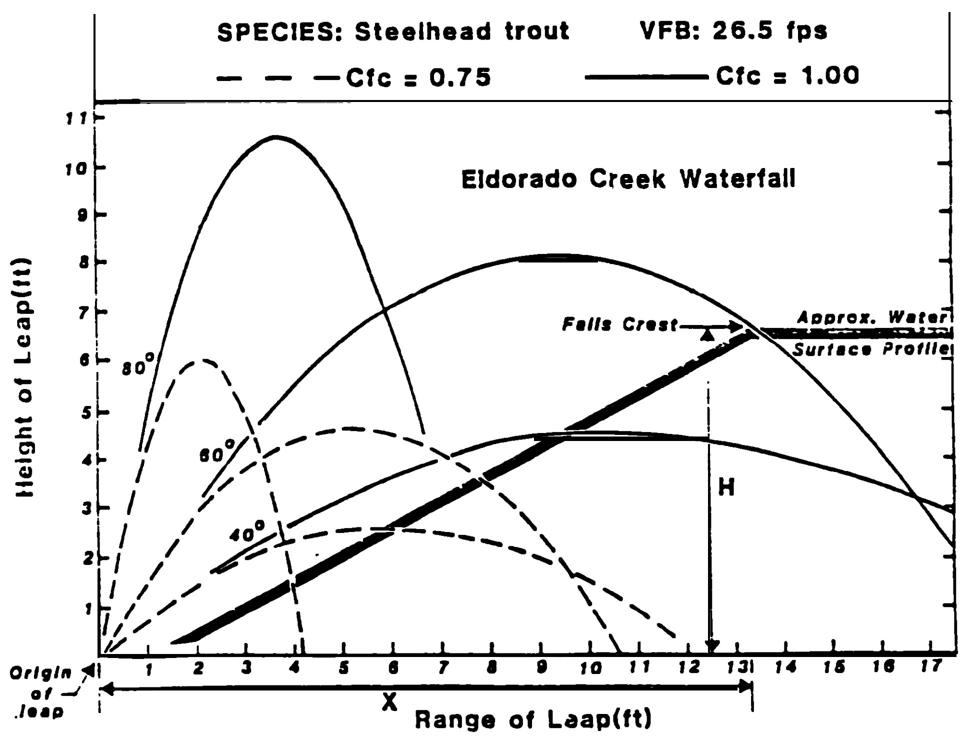


Figure 1. Eldorado Creek waterfall superimposed on steelhead leaping curves.

(1) Powers, P.D. 1984.

IF we consider blasting a channel down the face of the chute, the mean velocity will be :

$V = 1.49/n\ R^{2/3} S^{1/2}$ where: n = roughness coeff. ≈ 0.04

R = hydr. radius = $\frac{\text{Flow Area}}{\text{Wetted Perim.}}$

Assume chan. 2'W x 3'D: S = Channel slope = 7'/14' = 0.50

$R = A/p = \frac{3 \times 2}{2 + 2(3)} = \frac{6}{8} = 0.75$; $R^{2/3} = (0.75)^{2/3} = 0.825$

$V = \frac{1.49}{0.04}(0.825)(0.50)^{0.5} = 21.7\text{fps}$; $Q = 6(21.7) = 130\text{ cfs}$ TOO LARGE FOR THIS SITE

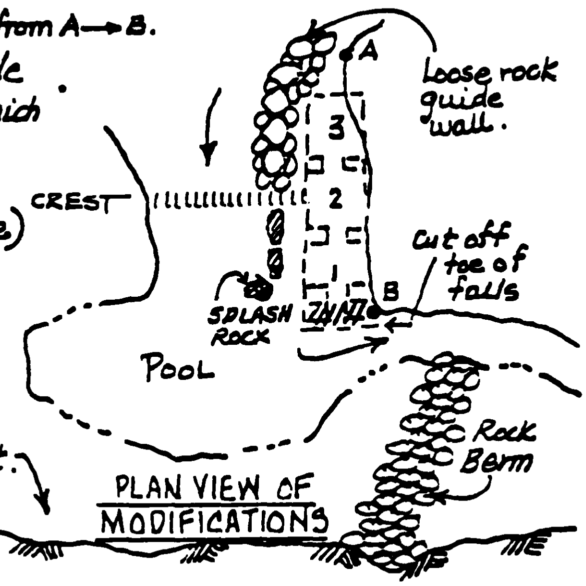
Burst Speeds: Chinook = 23fps; Steelhead = 27fps...

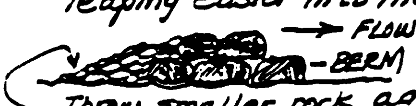
STEELHEAD could swim up the 3x2 chute channel, but flows would be too shallow for Chinook during the low flow migration season.

SOLUTIONS:

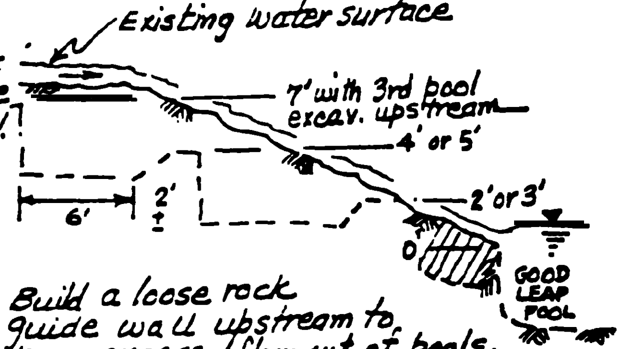
A better alternative would be to blast a series of three pools down the left (south) side of the barrier against the cliff.

1. Run a profile down the left side from A→B.
2. Try to locate a low point in the profile between (A) and the crest from which to start the pools.
3. Cut the pools as shown for Site No. 1 on page 3. (same type)
4. The first two pools from the lower pool up towards the crest can have leaps of 2-3' and the last one can make up the difference. The approximate profile is shown below on the right.
5. Remove the splash rock. Leave other two larger outcrops.
6. Stack the largest rocks avaible and add them to the downstream pile to form a loose rock berm as shown in the sketch. This will raise the lower pool elevation and make leaping easier into the first pool.





Throw smaller rock against the upstream side to help reduce flow through the rock berm.



7. Build a loose rock guide wall upstream to keep excess flow out of pools.

Steelhead will be better able to leap the falls with the rock berm in place, too, because the tailwater (pool) will rise faster than the headwater.

SITE No. 4

This falls could be passable by steelhead at higher flows, but is definitely a barrier when the pool depth downstream is less than 3 or 4'. The obvious steps to improve passage are:

(1) Blast a 3-4' pool about 8' square at the base of the falls;

(2) Remove the rock from the center of the falls crest, and the smaller ones in the upstream pool;

(3) Remove the larger rock on the right end of the falls crest to allow overflows to go down the right side; and

(4) Remove loose rocks from the downstream pool area and place them on the right end of the next crest downstream of the tailwater pool. Arrange the rocks on roadfill to form stable overflow bypass during higher flows; and

(5) Clean (blast) rock from under face of waterfall which causes flow to be deflected. Waterfall jet should have a clear trajectory to the plunge pool.

Some photographs are appended which are marked to denote some of the problems mentioned above; also, color slides are appended in a plastic sheet which show some of the same features.

The numbers on the photos correspond to the numbers on the site sketches for SITES 1-3 in the text.

THE REPORT ON CROOKED FORK BARRIERS WILL BE SUBMITTED SEPARATELY.

HYDROLOGY OF ELDORADO CREEK:

FLOW DATA FROM STORET CL 1120 & U.S.G.S. RECORDS

DATE	ELDORADO CR. FLOW (cfs)	No. 13339500 LOLO. CR. GAGE FLOW (cfs)	CLEARWATER R. GAGE (Orofino) (cfs)
10-25-79	8		
3-12-80	94	554	5580
4-7-80	71	638	5140
4-17-80	250	934	11100
5-27-80	338	(1800) 3380 (26th)	(29500) 37300 (26th)
7-30-80	32	94	3060
9-9-80	23	63	1570
9-16-80	23	67	1740
		MEAN FLOW (1980) = 313 cfs	MEAN FLOW (1980) = 7656 cfs
			LONG-TERM MEAN = 8939 cfs.

(DATA PLOTTED ON GRAPH ON PAGE 8A)

= MONTHLY FLOWS =

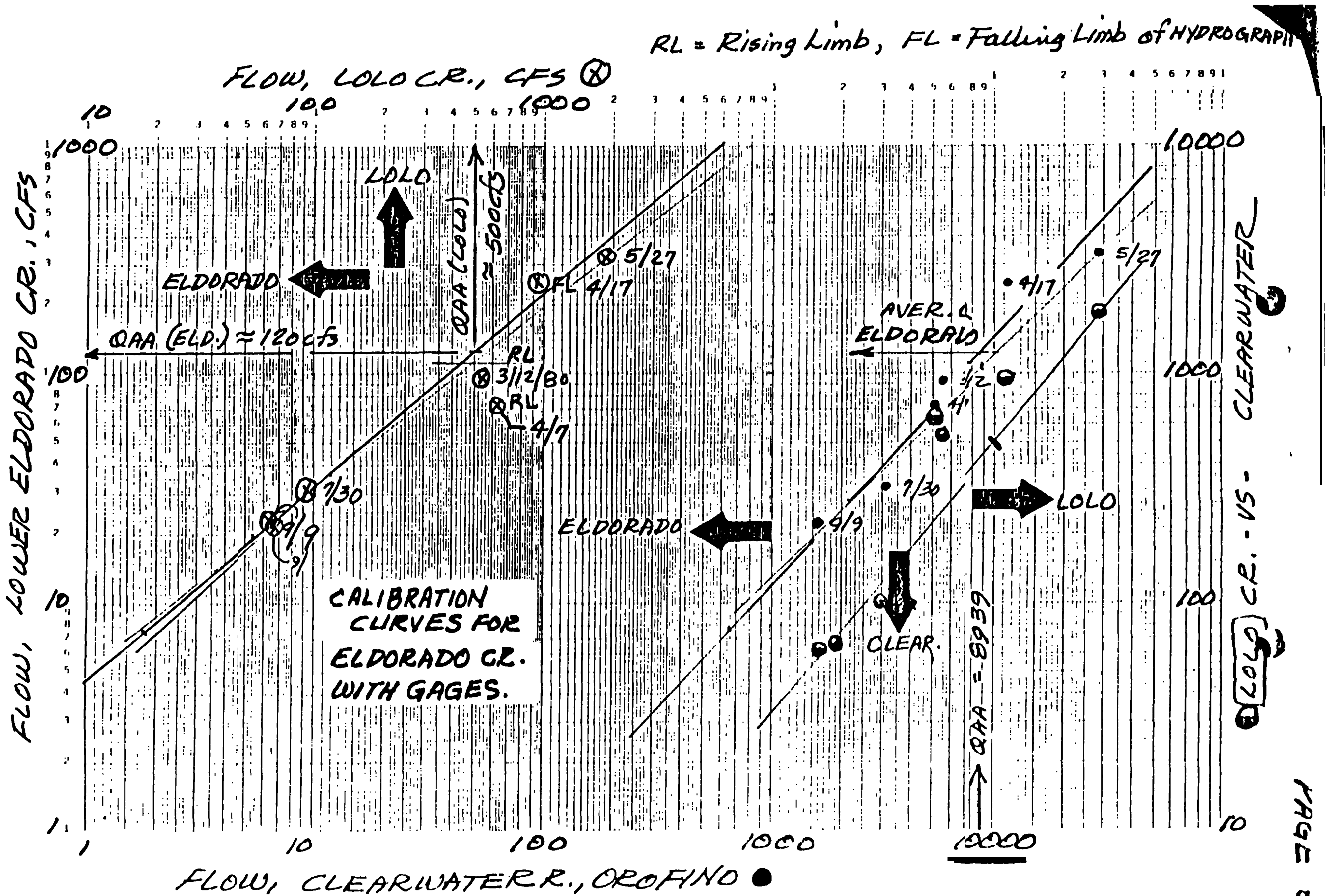
LOLO CR. GAGE No. 13339500 LOW. AVERAGE AND HIGH FLOW YEARS

WATER YEARS	MONTHS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
LOW YEAR 1980 Q, AV. = 313		76	59	146	166	286	491	781	772	663	181	71	80
%Av.		0.24	0.19	0.47	0.53	0.91	1.57	2.50	2.46	2.12	0.58	0.23	0.26
AVER. YEAR 1981 Q, AV. 324 cfs		57	123	338	231	602	387	553	455	787	262	71	54
% Av.		0.17	0.38	1.04	0.71	1.86	1.19	1.71	1.40	2.43	0.81	0.22	0.17
HIGH YEAR 1982 Q, AV. 448 cfs		73	118	247	190	957	884	1062	1006	493	260	73	65
% Aver.		0.16	0.26	0.55	0.42	2.14	1.97	2.37	2.24	1.10	0.58	0.16	0.14

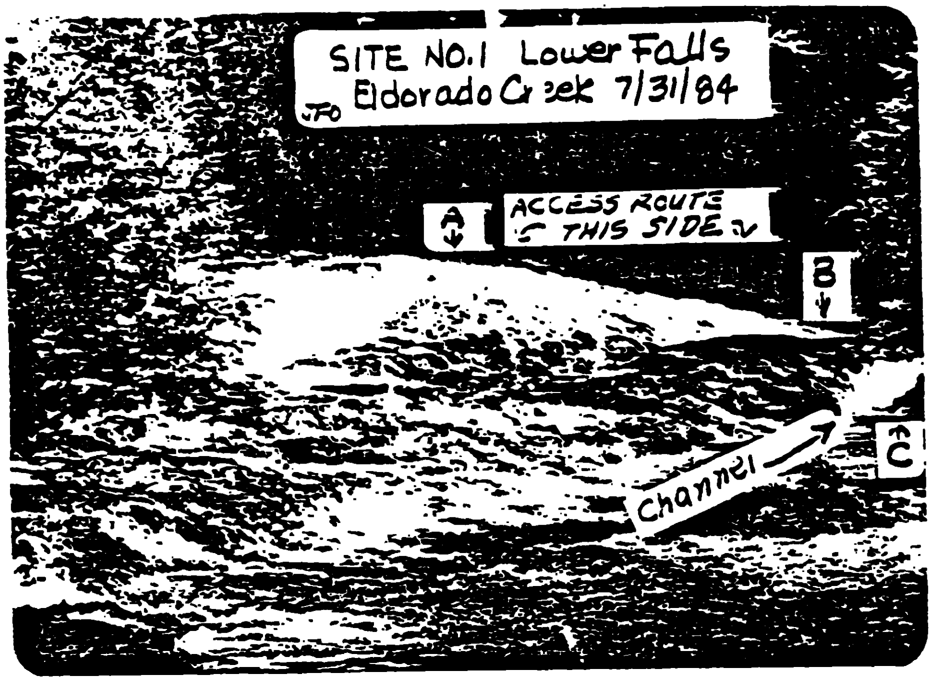
FROM GRAPH ON PAGE 9, From Clearwater Gage: Average Annual Flow Eldorado Creek ≈ 120 cfs.

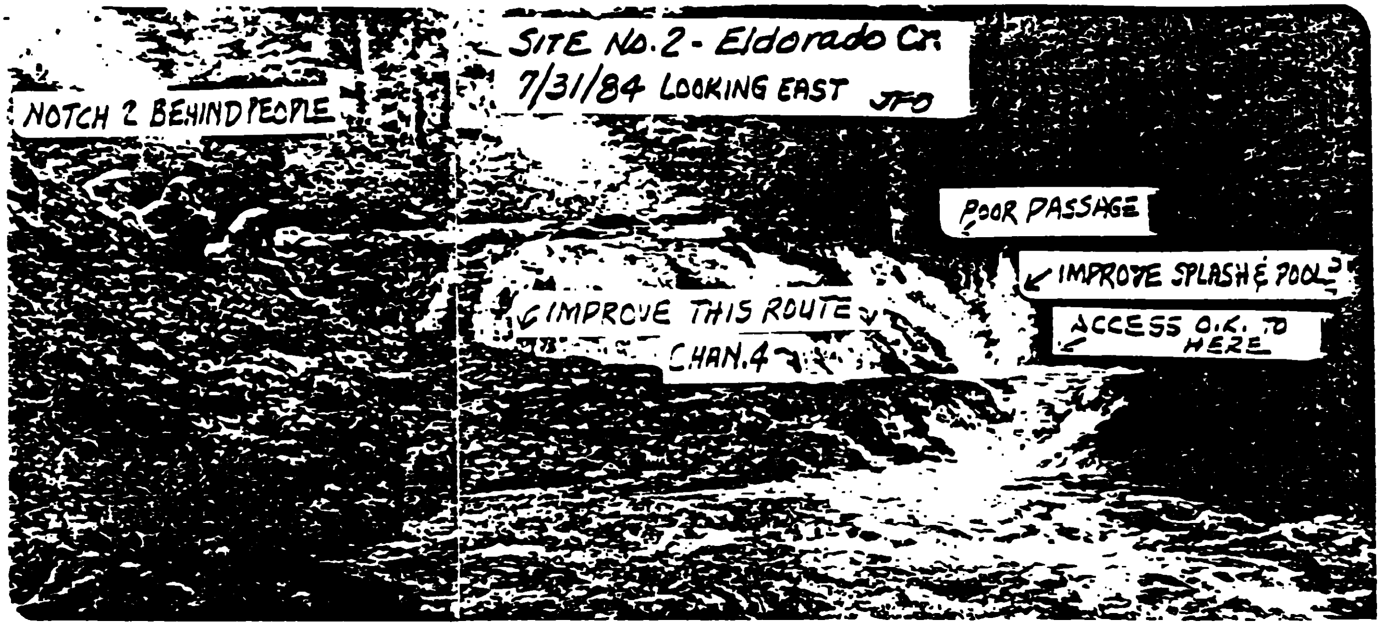
STEELHEAD MIGRATION FLOWS (APR-MAY) = (1.4 - 2.5) Aver. Flow
= 170 - 300 cfs

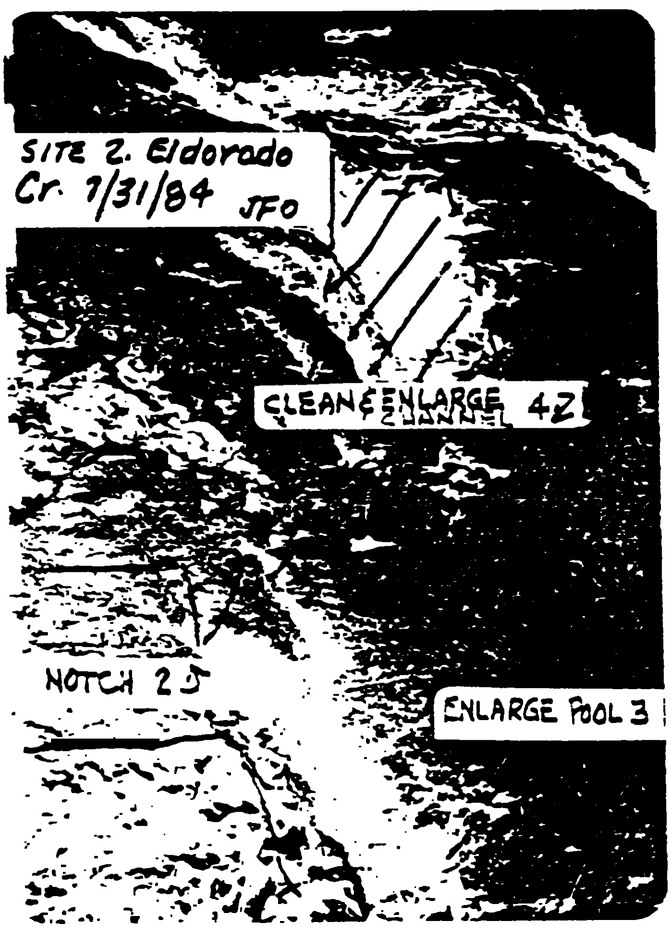
CHINOOK MIGRATION FLOWS (JULY-AUG) = (0.20 - 0.80) Aver. Flow
= 24 - 96 cfs



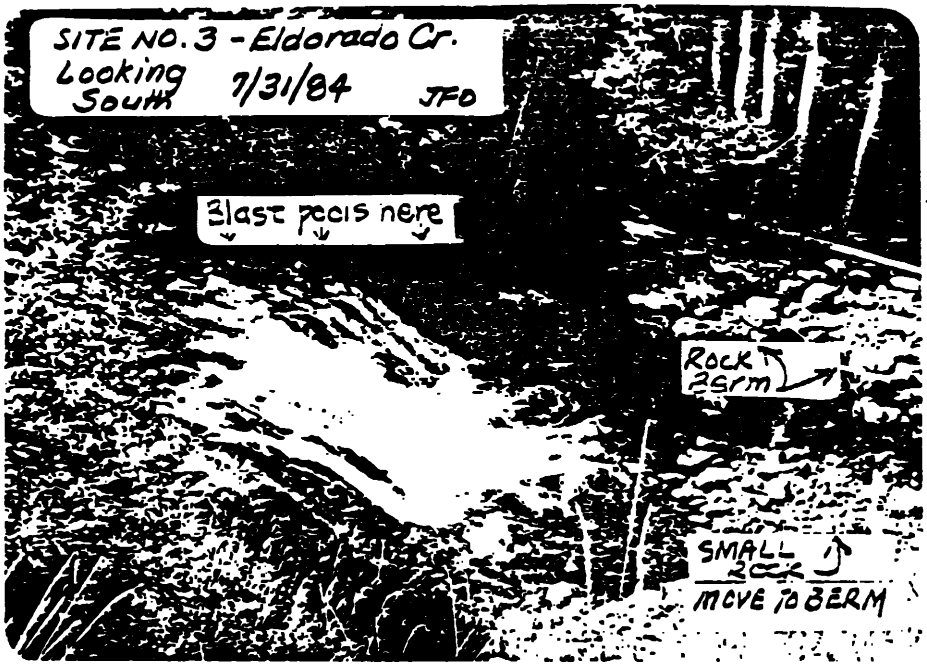
J.F. Orsborn 8/7/84


SITE NO.1 Lower Falls
Eldorado Creek 7/31/84
JFO
A
ACCESS ROUTE
THIS SIDE
B
C
Channel

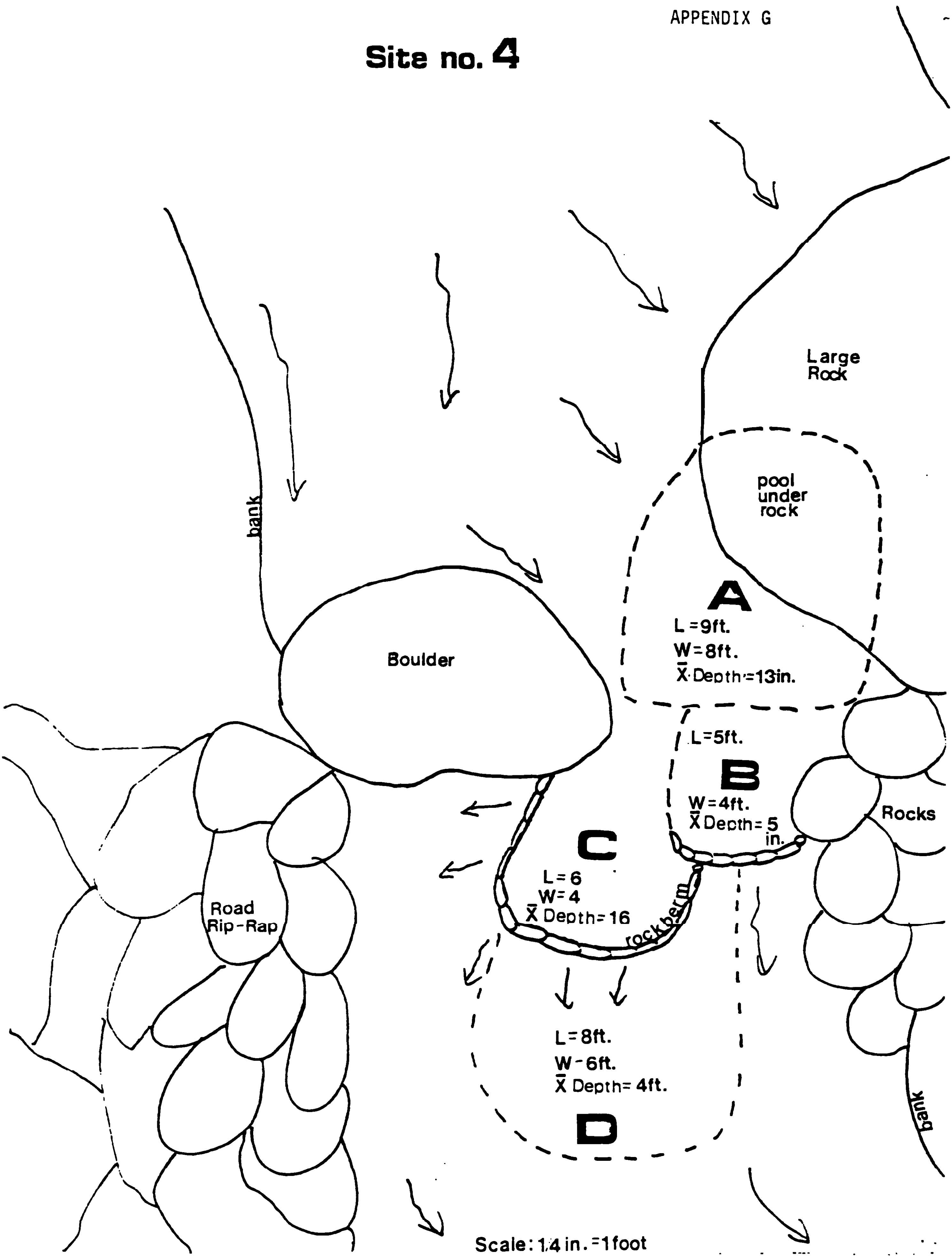

SITE No. 2 - Eldorado Cr.
7/31/84 LOOKING EAST JFO
NOTCH 2 BEHIND PEOPLE
POOR PASSAGE
IMPROVE SPLASH & POOL 3
IMPROVE THIS ROUTE
CHAN. 4
ACCESS O.K. TO HERE


SITE 2. Eldorado Cr. 7/31/84 JFO
CLEAN & ENLARGE CHANNEL 4Z
NOTCH 2
ENLARGE POOL 3


SITE NO. 2 Eldorado Cr.
7/31/84 NOTCH AT N. END 2 JFO
LOOKING UPSTREAM

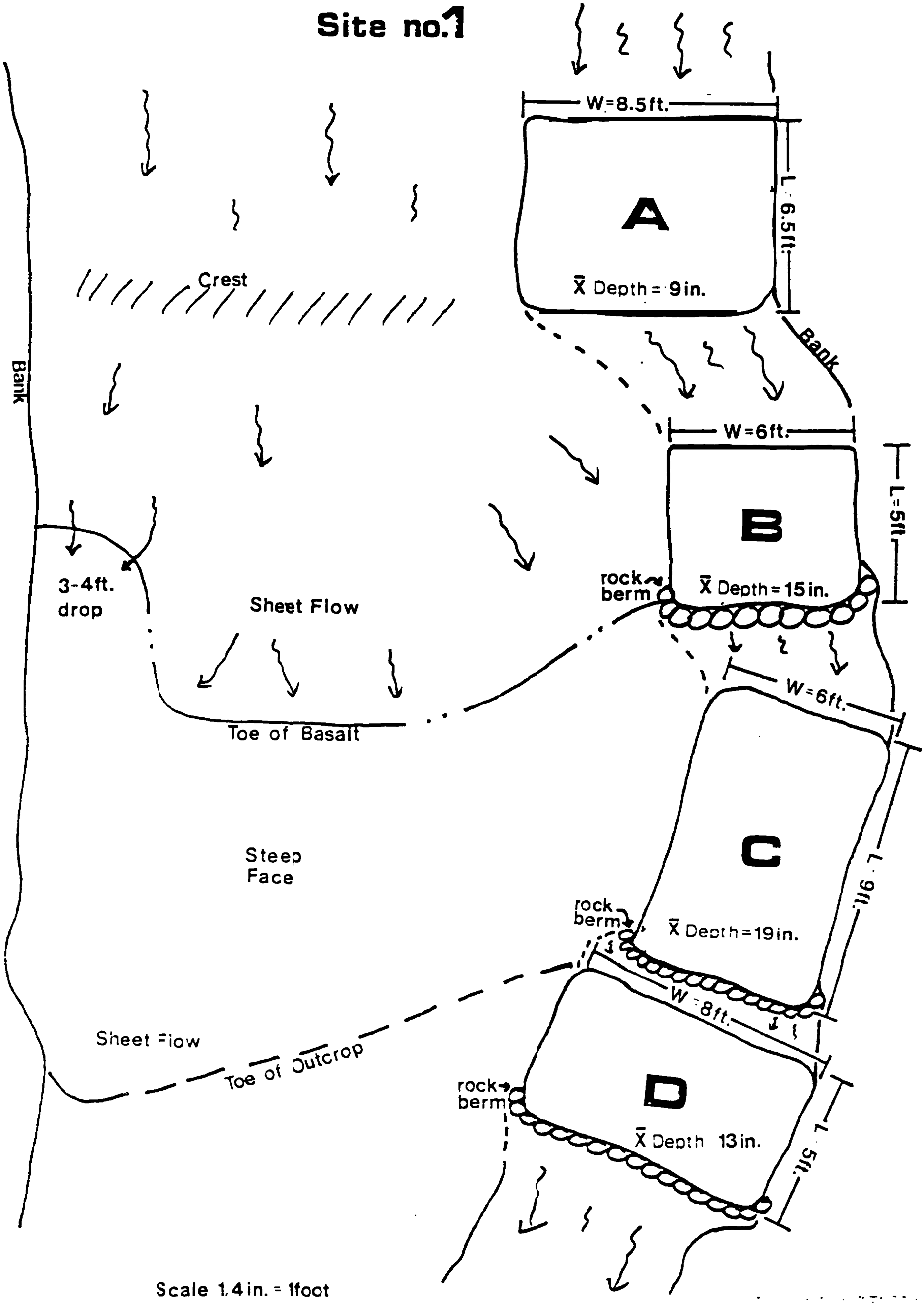

SITE NO. 3 - Eldorado Cr.
Looking South 7/31/84 JFO
Blast pools here
Rock Berm
SMALL ROCK
MOVE TO BERM

Site no. 4



Scale: 1/4 in. =1foot

Site no.1



Scale 1.4 in. = 1foot

B. <u>Site Number 2</u>:

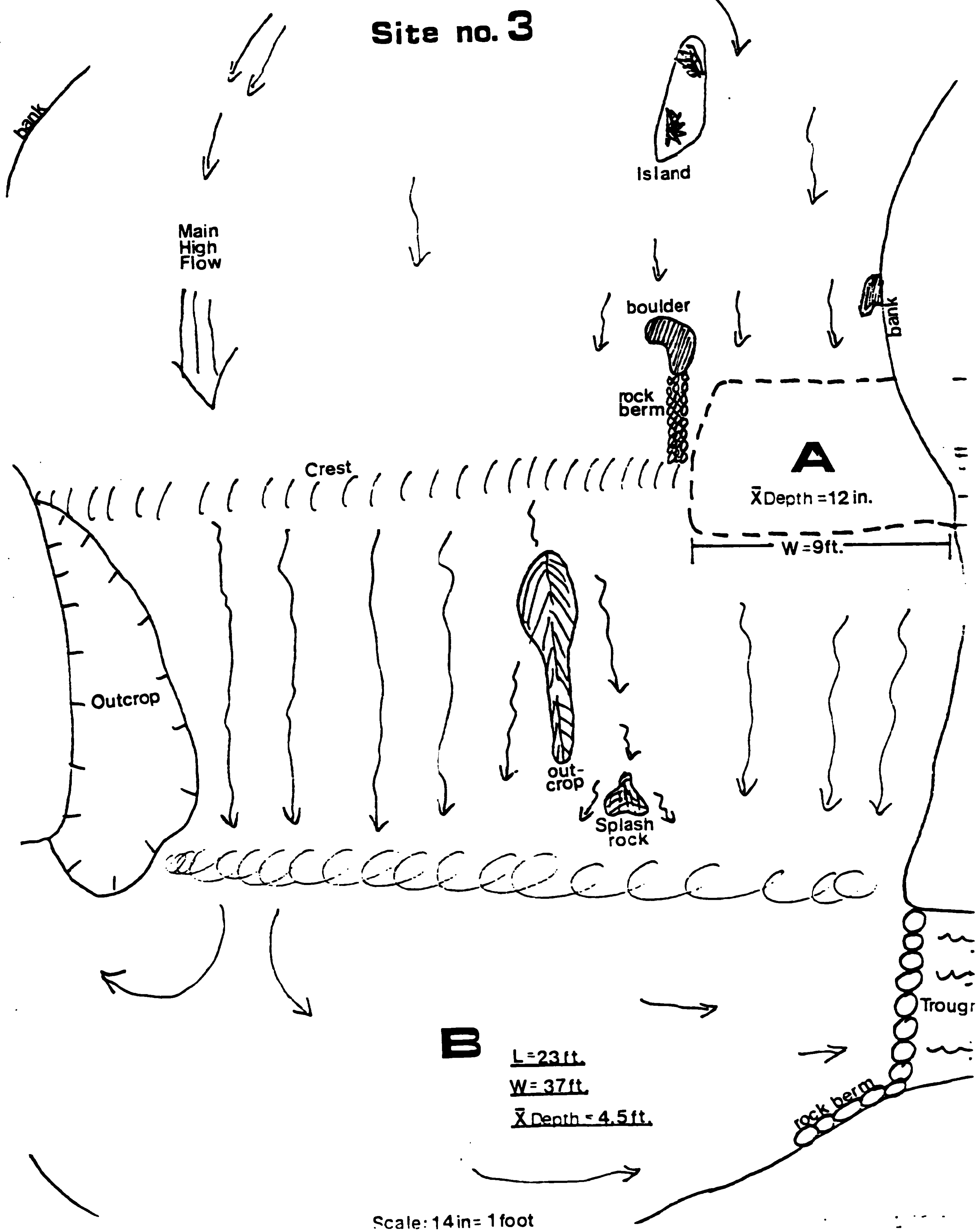
1. Pool A(Upstream)	Designed	Measured	Treatment
a. length	6 ft.	9 ft.	Adequate
b. width	8 ft.	6 ft.	Inadequate
c. mean depth	2-3 ft.	1.4 ft.	Inadequate
d. vertical drop to pool (B)	2-3 ft.	5 ft.	Inadequate

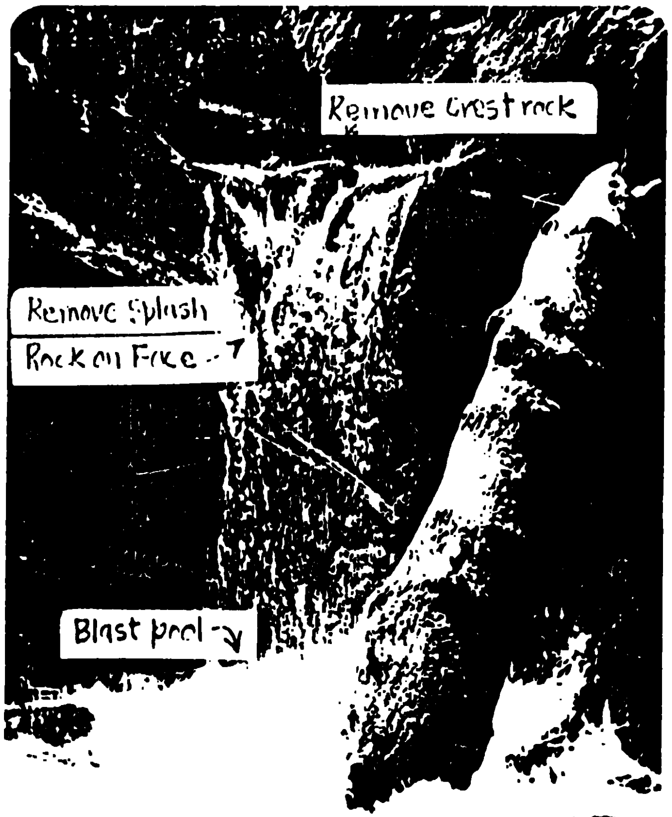
2. Pool B			
a. length	6-3 ft.	9 ft.	Adequate
b. width	6-8 ft.	5 ft.	Adequate
c. mean depth	6 ft.	2.1 ft.	Inadequate
d. vertical drop to pool (C)	1-2 ft.	2 ft.	Adequate

3. Pool C (Not designed)			
a. length	0	4 ft.	Adequate
b. width	0	4 ft.	Adequate
c. mean depth	0	1.1 ft.	Inadequate
d. vertical drop to pool (D)	0	1 ft.	Adequate

4. Pool D (Natural condition-not treated)			
a. length	0	6 ft.	Adequate
b. width	0	3 ft.	Inadequate
c. mean depth	0	4 ft.	Adequate
d. vertical drop to pool (E)	0	2-3 ft.	Adequate

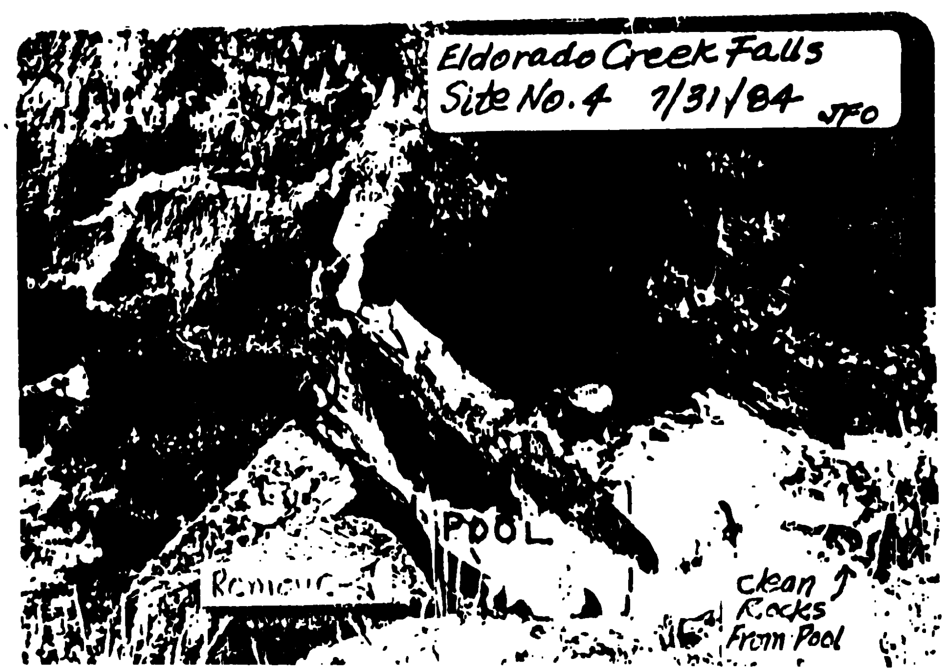
5. Pool E (Not designed)			
a. length	0	5 ft.	Adequate
b. width	0	4 ft.	inadequate
c. mean depth	0	2.1 ft.	Adequate
d. vertical drop to main channel	0	2 ft.	Adequate


Site no. 3
bank
Island
Main High Flow
boulder
bank
rock berm
Crest
A
X̄ Depth = 12 in.
W = 9 ft.
Outcrop
out-crop
Splash rock
Trougr
B
L = 23 ft.
W = 37 ft.
X̄ Depth = 4.5 ft.
rock berm
Scale: 14 in = 1 foot



Eldorado Cr. SITE 4
7/31/84 JFO

Road Fill from Toe - Eldorado
Cr. Site #4 Falls 7/31/84 JFO



Eldorado Creek Falls
Site No. 4 7/31/84 JFO

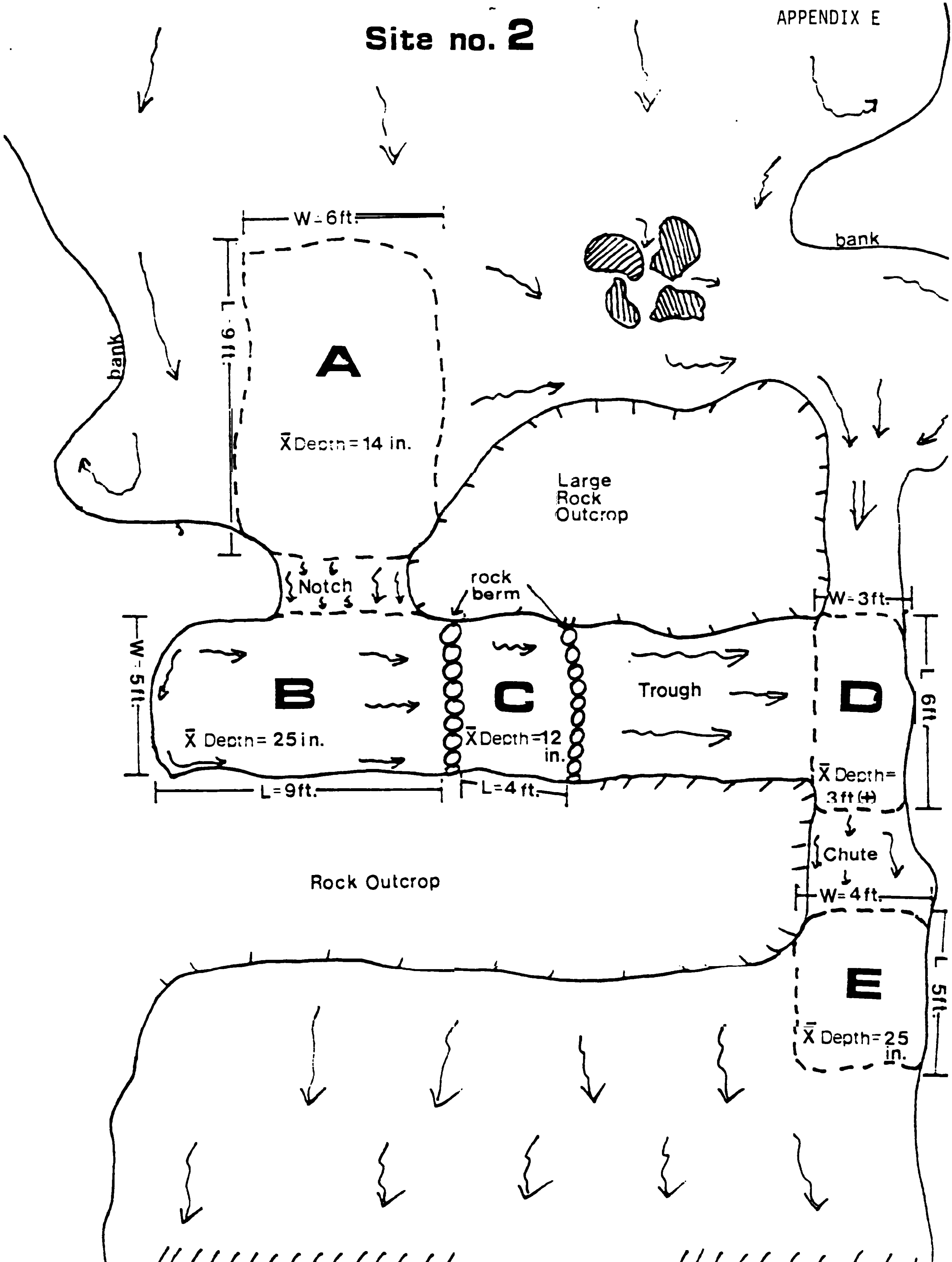
Appendix H

Comparison of Designed and Measured Pool Parameters by Site after 1984 Blasting

A. Site Number 1:

1. Pool A (Upstream)	Designed	Measured	Treatment
a. length	6-8 ft.	6.5 ft.	Adequate
b. width	6 ft.	8.5 ft.	Adequate
c. mean depth	2 ft.	0.75 ft.	Inadequate
d. vertical drop to pool (C)	2-3 ft.	5.0 ft.	Inadequate
2. Pool B			
a. length	6-8 ft.	5 ft.	Inadequate
b. width	6 ft	6 ft.	Adequate
c. mean depth	2 ft.	1.3 ft.	Inadequate
d. vertical drop to pool (C)	2-3 ft.	2.5 ft.	Adequate
3. Pool C			
a. length	6-8 ft.	9 ft.	Adequate
b. width	6 ft.	6 ft.	Adequate
c. mean depth	2 ft.	1.6 ft.	Adequate
d. vertical drop to pool (D)	2-3 ft.	1 ft.	Adequate
4. Pool D			
a. length	6-8 ft.	5 ft.	Inadequate
b. width	6 ft.	8 ft.	Adequate
c. mean depth	2 ft.	1.1 ft.	Inadequate
d. vertical drop to main channel	2-3 ft.	1 ft	Adequate

Site no. 2



Scale: 1 4 in = 1 foot

C. Site Number 3:	Designed	Measured	Treatment
1. Pool A (Upstream)			
a. length	6 ft.	5 ft.	Inadequate
b. width	7 ft.	g ft.	Adequate
c. mean depth	2 ft.	1 ft.	Inadequate
d. vertical drop	2-3 ft.	5-6 ft.	Inadequate
2. Pool #2 (Designed-Not treated)			
a. length	6 ft.	0	To be treated
b. width	7 ft.	0	To be treated
c. mean depth	2 ft.	0	To be treated
d. vertical drop to pool (#1)	2-3 ft.	0	To be treated
3. Pool #1 (Designed-Not treated)			
a. length	6 ft.		To be treated
b. width	7 ft.		To be treated
c. mean depth	2 ft.		To be treated
d. vertical drop to main pool	2-3 ft.		To be treated
4. Pool B			
a. length	0	20-25 ft.	Adequate
b. width	0	35-40 ft.	Adequate
c. mean depth	4(+) ft.	4.5 ft.	Adequate
d. vertical drop	2 ft.	2 ft.	Adequate

D. Site Number 4:

1. Pool A (Upstream- Not designed 1

	Designed	Measured	Treatment
a. length	0	9 ft.	Adequate
b. width	0	8 ft.	Adequate
c. mean depth	0	1.2 ft.	Adequate
d. vertical drop to pool (B)	0	3 ft.	Adequate

2. Pool B (Not designed)

a. length	0	5 ft.	Adequate
b. width	0	4 ft.	Inadequate
c. mean depth	0	0.4 ft.	Inadequate
d. vertical drop to pool (C)	0	2 ft.	Adequate

3. Pool C

a. length	6 ft.	6 ft.	Adequate
b. width	6-8 ft.	4 ft.	Inadequate
c. mean depth	2 ft.	1.4 ft.	Inadequate
d. Vertical drop to pool (D)	2 ft.	2 ft.	Adequate

4. Pool D (Natural not designed or treated)

a. length	0	8 ft.	Adequate
b. width	0	6 ft.	Adequate
c. mean depth	0	4 ft.	Adequate
d. vertical drop to main channel	0	0 ft.	Adequate

UPPER CROOKED FORK FISH BARRIER REMOVAL

Powell Ranger District

Clearwater National Forest

Region 1

BPA Project #DE-AI79-84BP 16535

Columbia River Basin Fish And Wildlife Program

Northwest Power Planning Council

Northwest Power Act (P.L. 96-501)

An Annual Report Submitted to the
Bonneville Power Administration

by

Richard P. Kramer
District Fisheries Biologist
Clearwater National Forest

Patrick Murphy
Fisheries Technician

F.A. Espinosa, Jr.
Forest Fisheries Biologist
Project Leader

TABLE OF CONTENTS

ABSTRACT

Crooked Fork Creek is one of the principal tributaries of the Lochsa River. It contains the bulk of the remaining high quality spawning and rearing habitats for anadromous fish on the Clearwater National Forest. It is estimated that 25 percent of the total chinook salmon and 25 percent of the total steelhead smolt production of the Clearwater National Forest emanate from this drainage. The long-term ability to restore anadromous fish runs to the upper Lochsa system is dependent upon increasing the available spawning habitat in the Crooked Fork Drainage.

Recent stream and habitat evaluation surveys established that several natural waterfalls and rock chutes totally preclude upstream migration of spring chinook salmon during late summer low flows. At some high flows, summer steelhead are able to negotiate the barriers.

Seven major barriers and five partial barrierswere removed during the summer of 1984. Deep cake-off pools and resting areas were created to increase fish passage. Some of the barriers will have to be re-evaluated to determine if additional blasting is needed to provide full passage.

INTRODUCTION

Crooked Fork Creek is one of the principal tributaries of the Lochsa River. It contains the bulk of the remaining high quality spawning and rearing habitats for anadromous fish on the Clearwater National Forest. It is estimated that 25 percent of the total chinook salmon and 25 percent of the total steelhead smolt production of the Clearwater National Forest emanate from this drainage. The long-term ability to restore anadromous fish runs to the upper Lochsa system is dependent upon increasing the available spawning habitat in the Crooked Fork Drainage.

Recent stream and habitat evaluation surveys established that several natural waterfalls and rock chutes totally preclude upstream migration of spring chinook salmon during late summer low flows (fig 1). At some high flows, summer steelhead are able to negotiate the barriers. However, fish population surveys indicate that successful passage of steelhead is infrequent and of low magnitude. Juvenile steelhead densities are much lower above than below the barriers. The barriers were selectively drilled and shot with explosives in a manner that creates stair-step resting' and take-off (jump) pools.

DESCRIPTION OF PROJECT AREA

Crooked Fork and White Sand Creeks reach confluence near Powell, Idaho (3,500 ft. elevation) to form the Lochsa River (figs. 1 & 2). Crooked *Fork Creek* is In fact a small river draining approximately 93,000 acres of the Bitterroot Mountains and covering some 24 miles.

The Crooked Fork drains a variety of landforms that include glacial, valley trains, steep breaklands, colluvial drift slopes, and alluvial flood plains. Breaklands and alluvial plains dominate the watershed. Granitic soils of the Idaho Batholith typify the geology of the area. The stream flows through dense, mixed coniferous stands or' western red cedar, Douglas fir, Englemann spruce, unite pine, ponderosa pine, and larch. A few deciduous species are present within the riparian zones.

Crooked Fork has experienced extensive timber harvesting and road construction for the past two decades. Most of this activity has been concentrated in it's lower reaches and in the Brushy Fork subdrainage. Impacts associated with sedimentation and over-harvesting *In* the riparian zones have been moderate. The upper reaches of Crooked Fork are lightly developed and are in a pristine condition.

The Crooked Fork Watershed is under the management of mixed ownership; the U.S. Forest Service and Plum Creek Timber Company. Crooked Fork is characterized by a checkerboard pattern with Plum Creek owning some *34,090 acres* (23%).

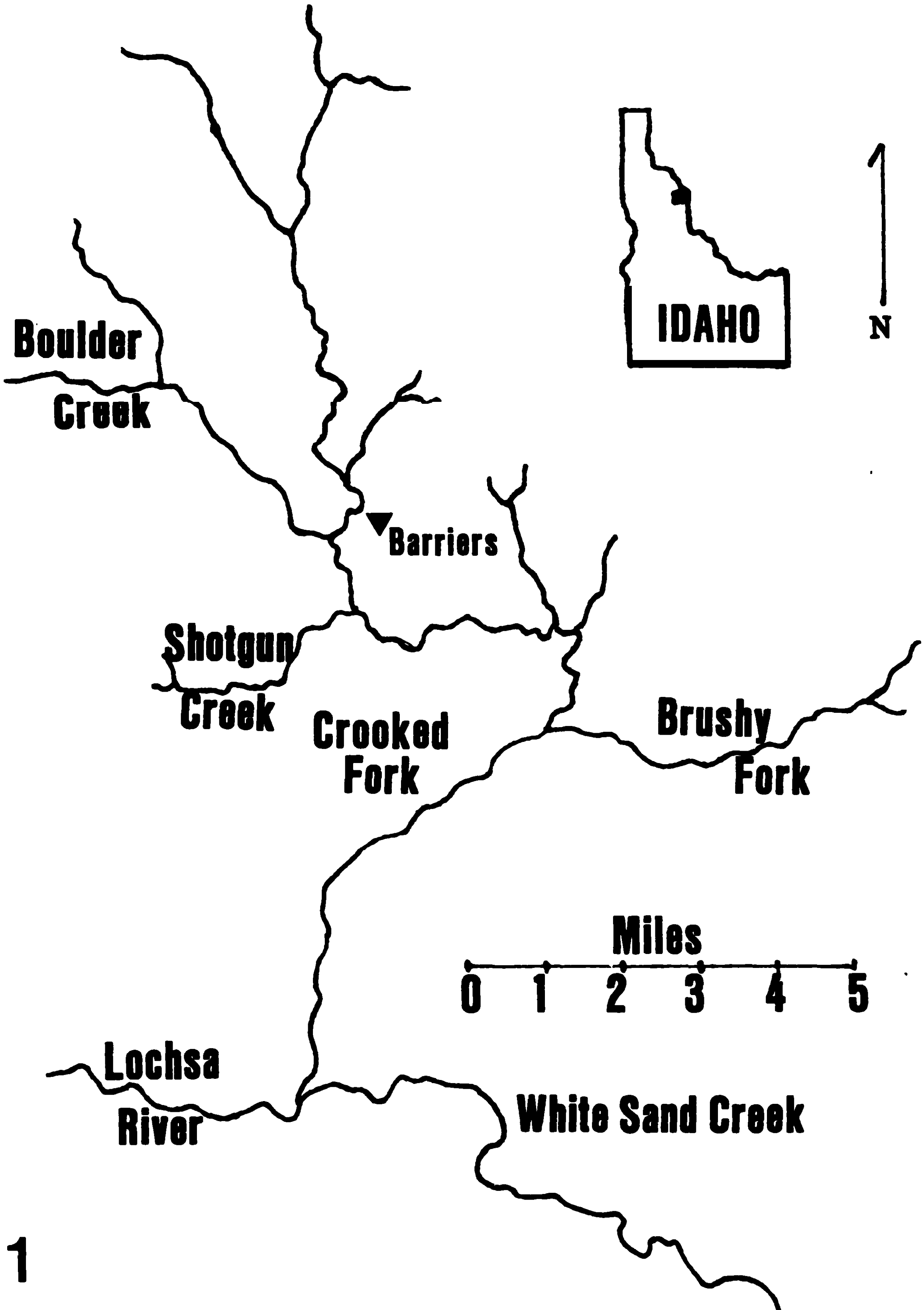


FIG. 1

Crooked Fork and White Sand drainages   Location of Project Area

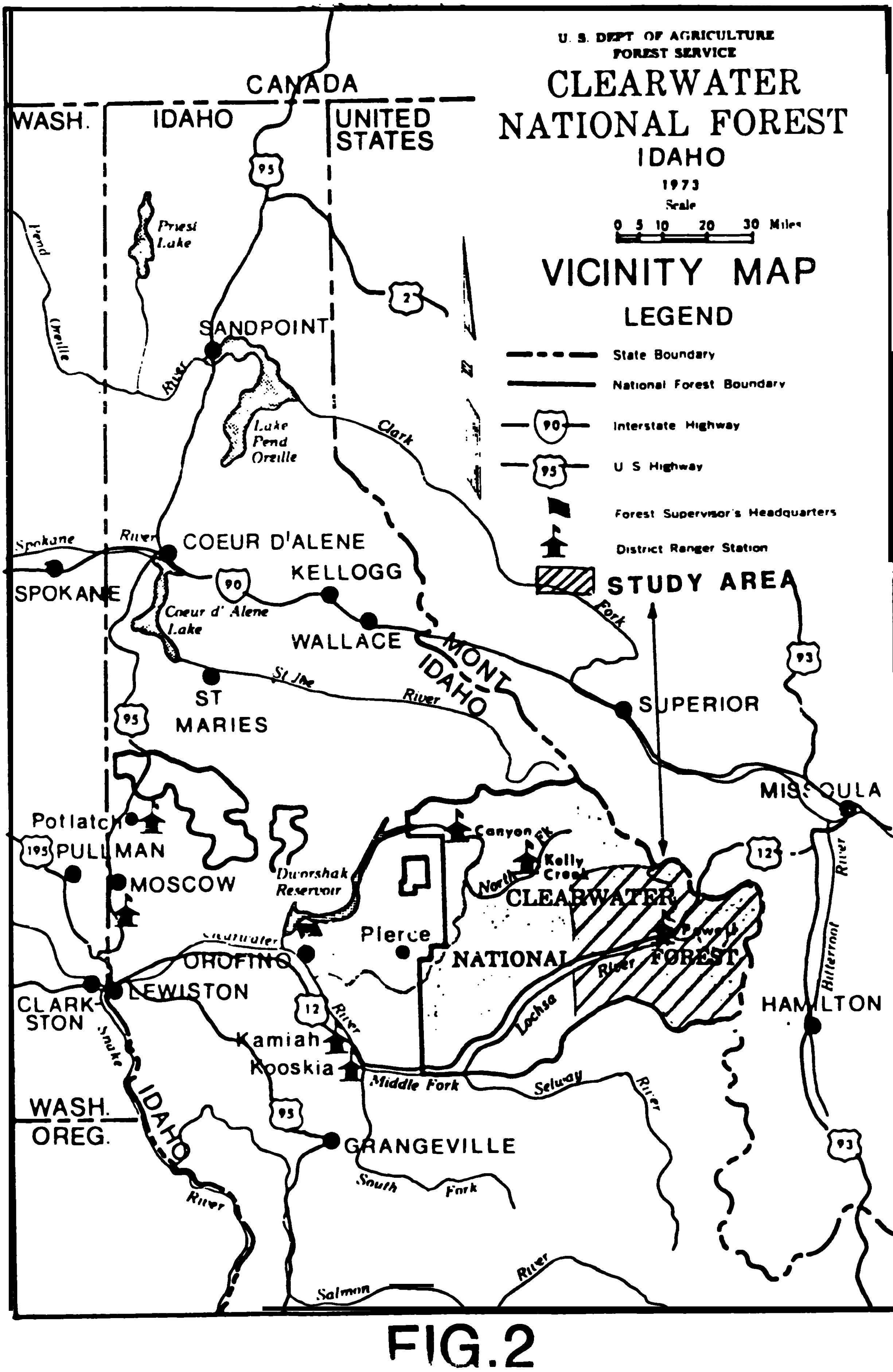

U. S. DEPT OF AGRICULTURE
FOREST SERVICE
CLEARWATER
NATIONAL FOREST
IDAHO
1973
Scale
0 5 10 20 30 Miles
VICINITY MAP
LEGEND
State Boundary
National Forest Boundary
Interstate Highway
U S Highway
Forest Supervisor's Headquarters
District Ranger Station
STUDY AREA
CANADA
WASH.
IDAHO
UNITED STATES
Priest Lake
Pend Oreille River
SANDPOINT
Lake Pend Oreille
Clark Fork
Spokane River
COEUR D'ALENE
SPOKANE
KELLOGG
WALLACE
Coeur d' Alene Lake
MONT.
IDAHO
St Joe River
ST MARIES
SUPERIOR
MISSOULA
Potlatch
PULLMAN
MOSCOW
Canyon Ck
Kelly Creek
North Fk
Dworshak Reservoir
CLEARWATER
NATIONAL
FOREST
Pierce
Powell
OROFINO
LEWISTON
CLARKSTON
Lochsa River
Bitterroot River
HAMILTON
Kamiah
Kooskia
Middle Fork
Selway River
Snake River
WASH.
OREG.
IDAHO
GRANGEVILLE
South Fork
Salmon River

FIG. 2

The Project area is located approximately two miles upstream from the confluence of Boulder Creek (T. 38 N., R. 14 E., sec. 14). The area is accessible only by foot or helicopter. Within the project area, Crooked Fork displays a mean discharge of 221 c.f.s. during steelhead spawning (April and May) and 37 c.f.s. during the salmon spawning period (July 15 - Sept 15). Crooked Fork shows a mean stream width and depth of 26 feet and 0.7 feet respectively (base flows). Within the project area, the creek had gradient with a mean OF 3.7 per-cent and range of 2.0 percent to 6.2 percent.

The stream substrate within the project area, consists of larger materials (Bedrock 21%, Boulder 26%, Rubble 41%). Above the project area, Crooked Fork displays a lower gradient and smaller substrate materials which provide good spawning areas. Most of the Crooked Fork barriers consists of long 15 to 30 ft, steeply inclined, granite rock aprons that contain no jump pools or resting areas. At low flows, only a thin layer of water flows over the aprons (Fig. 3). Extensive rearing areas for juvenile salmon and steelhead exist above the barriers. Provisions of access will open up 16 stream miles consisting: of 78 acres of rearing and 0.93 acres of spawning habitats for anadromous fish. Assuming the availability of seeding stock or increased escapement to the upper Lochsa area, the project would increase the system's smolt production by 27,000 salmon and 27,150 steelhead.

METHODS AND MATERIALS

The Crooked Fork project area was examined in late July to determine equipment needs, prepare a helispot, and mark the migration barriers. Only one area was located for a helispot (Fig. 4). On August 1, initial field activities began with transporting equipment and personnel to the project area. A base camp was set up adjacent to the helispot (Fig. 5). Work crews hiked in from the Crooked Fork road (595) which was approximately one mile from base camp. Additional equipment and personal gear was carried to base camp.

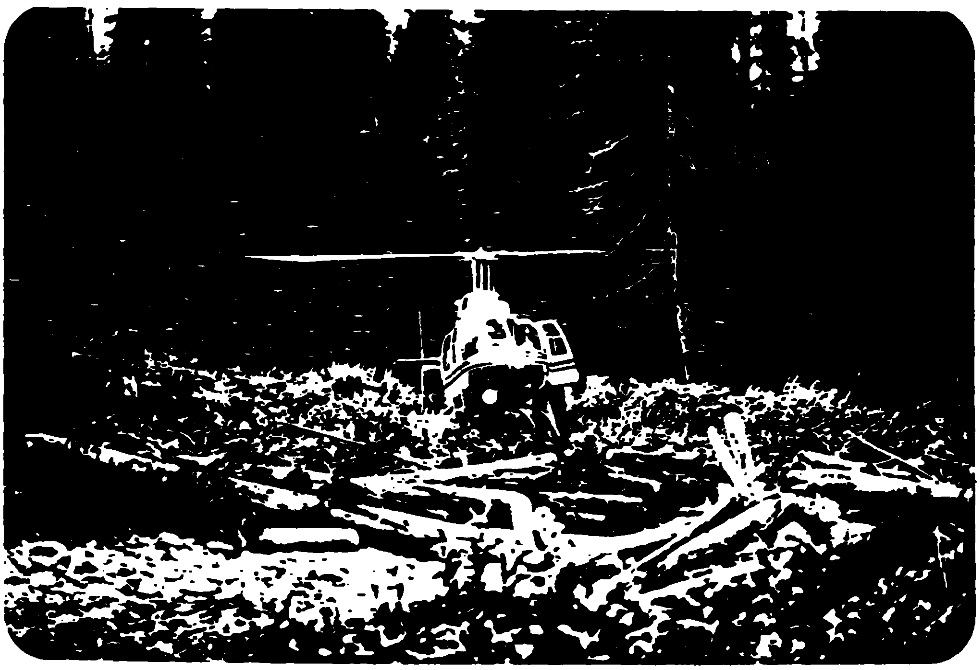
During the base camp set up, Forest Service personnel and Consultant, Jack Osborn, P. E., surveyed the project area to determine how to modify existing barriers (#4-7) to provide optimum fish passage (see Appendix B). Five smaller barriers were also located and discussed. The placement of drill holes and modifications were discussed with personnel. Due to time limitations and weather conditions, barriers #1 & 2 were not examined during the initial evaluation.

The modification work started on the downstream barrier (#7) and progressed upstream one mile to barrier #1. Drilling and blasting began on August 2, and proceeded throughout August. Equipment breakdown and personnel on District fires extended the Project completion time.

Figure 3 . Actual view of partial barrier No. 1.

Figure 4   Location of camp and helicopter landing site, upper Creek Fork 1984.

Figure 5. Helicopter being unloaded at camp.



Drilling which was done by a two man crew was the most time consuming part of the project. Using a Pionjar 120 rock drill and drill bits ranging from 1 1/2' to 4' long, blasting holes were drilled into the barrier substrate at predetermined locations (Fig. 6). Depending on the barrier size, the barrier was either drilled and shot once or drilled several times with blasting performed whenever- enough drill holes were created. On larger barriers with several obstructions, one obstruction was drilled and snot at a tine to evaluate the modification.

Blasting was achieved by using water gel, primacord and blasting cap3 (Fig. 7). A certified Forest Service blaster, experienced in rock blasting, loaded, set up, and shot the drill holes. After blasting, crew members hand Ricked boulders and rock fragments out of pools (Fig. 8). The material was either placed on shore or pushed downstream. Natural scouring in the spring will eventually dislodge any remaining materials.

During the project, before and after photos were taken of each barrier. Additional photos showing crews drilling and working were also taken.

RESULTS AND DISCUSSION

Approximately 252 shot holes ranging from 1 l/2 ft to over 4 ft deep were drilled on 12 barriers. About 170 lbs. of water gel were used together with primacord and blasting caps in 23 separate charges. In most case3 it was necessary to blast each pool several times to achieve the desired results. Evaluating the five smaller barriers, it was determined that the resulting modifications were successful. In each case, large jump pools and resting areas were created and no fish passage problems were observed. Res tin.; areas and jump pools were created in the seven large barriers, but several pools need evaluation next spring to determine if pool depth is adequate. Barrier #5 was the most difficult barrier to achieve desired results. The initial blast lowered the entire first step and created 9 higher falls. Additional blasting created a small jump pool on the first steps, out natural scouring is needed to deepen the pool.

The following is a narrative of the results and future needs of each barrier. See Osborn's (Appendix B) report for diagrams of barriers 4-7.

Barrier #

Barrier #1 was not an extremely difficult one for chinnok salmon passage and no problem for steelhead passage. Two 2-foot deep pools were created on the left side of the barrier (looking upstream) and should pose no future problems for chinook salmon. A channel was also cleared on the right side of this barrier to provide an additional pathway (figs. 9-10). This barrier will require no additional work.

Figure 6. Drilling a hole for exploxsives using a Pionjar rock drill at Site No. 7A, Crooked Fork Creek, 1984.

Figure 7. A charge ready to be set off at Site 3A.

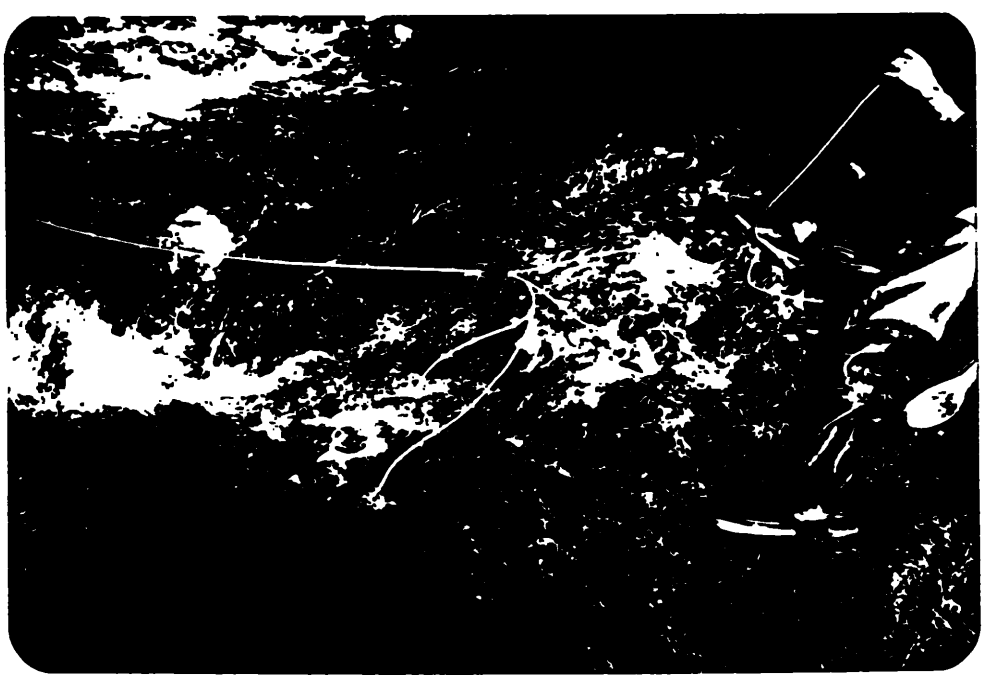


Figure 8. Removing loosened rock in barrier No. 7.

Figure 9. Pre-blasting view of barrier No. 1.

Figure 10. Post-blasting view of barrier No. 1.

Figure 11. View of barrier No. 2 after first blast.

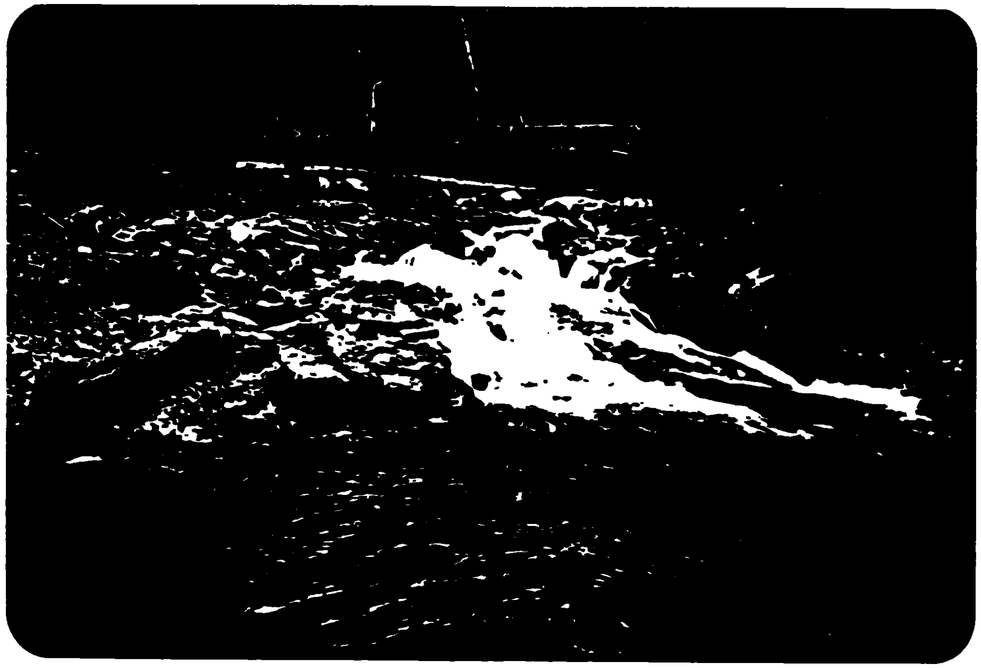


Figure 12. Post-blasting view of barrier No. 2.

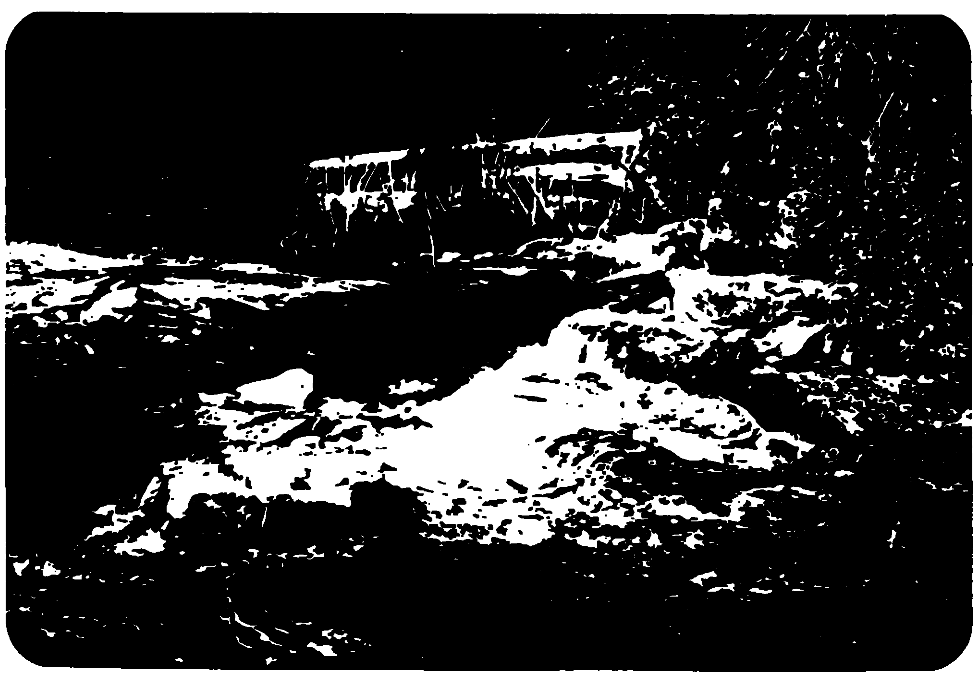


Figure 13. Aerial view of site No. 2 (Pre-blasting).

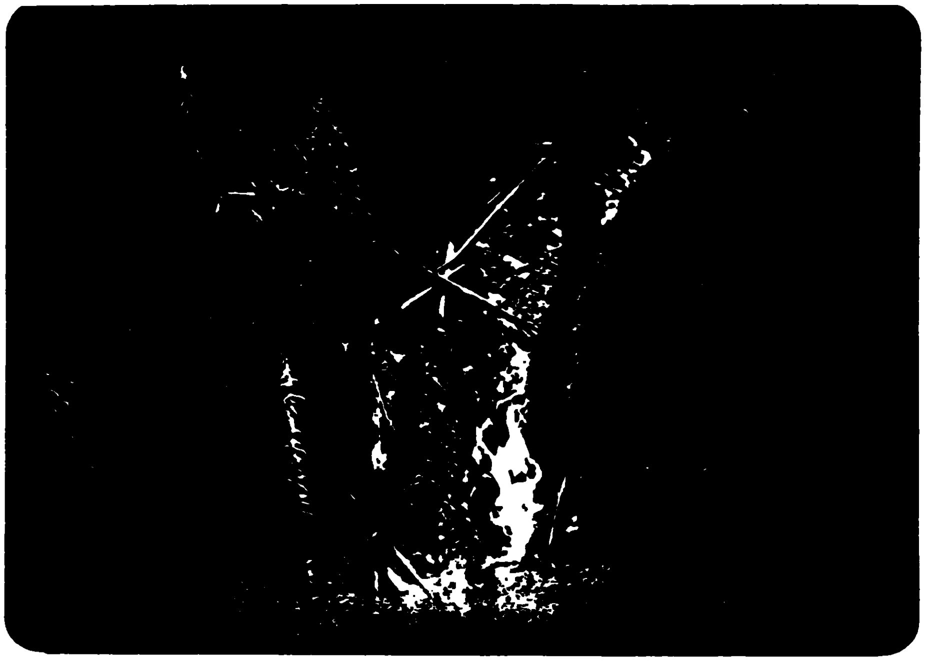


Figure 14. Pre-blasting (charge ready to be set off) view of barrier No. 2.

Figure 15 . Downstream view of barrier No. 3.

Figure 15 . Upstream view of barrier No. 3.

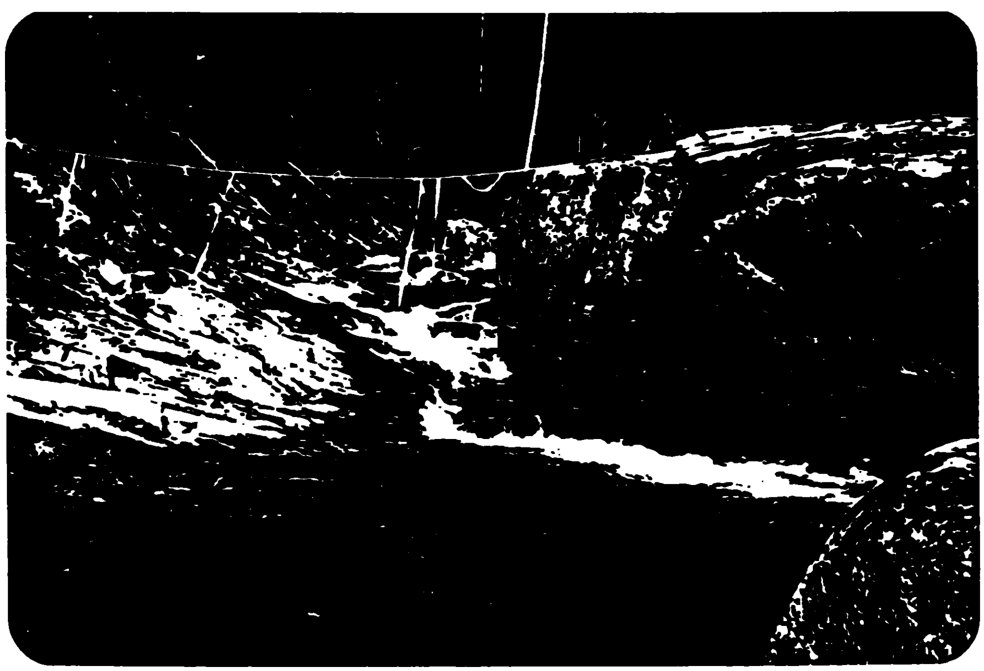


Figure 17. Post-blasting view of barrier No. 3.

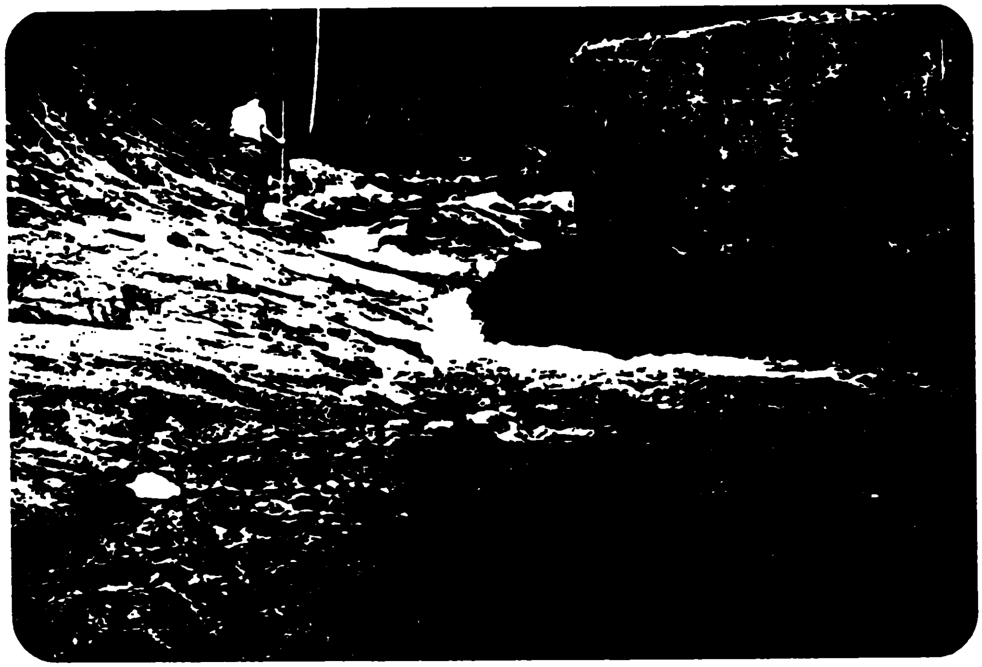


Figure 18. Pre-blasting view of barrier No. 4.

Figure 19. Upstream view of barrier No. 4 (pre-blasting). Note small alder branch used for marking drill holes.

Figure 20. Downstream view of barrier No. 4.

Figure 21. Post-blasting view of barrier No. 4. Note piles of rock on left.

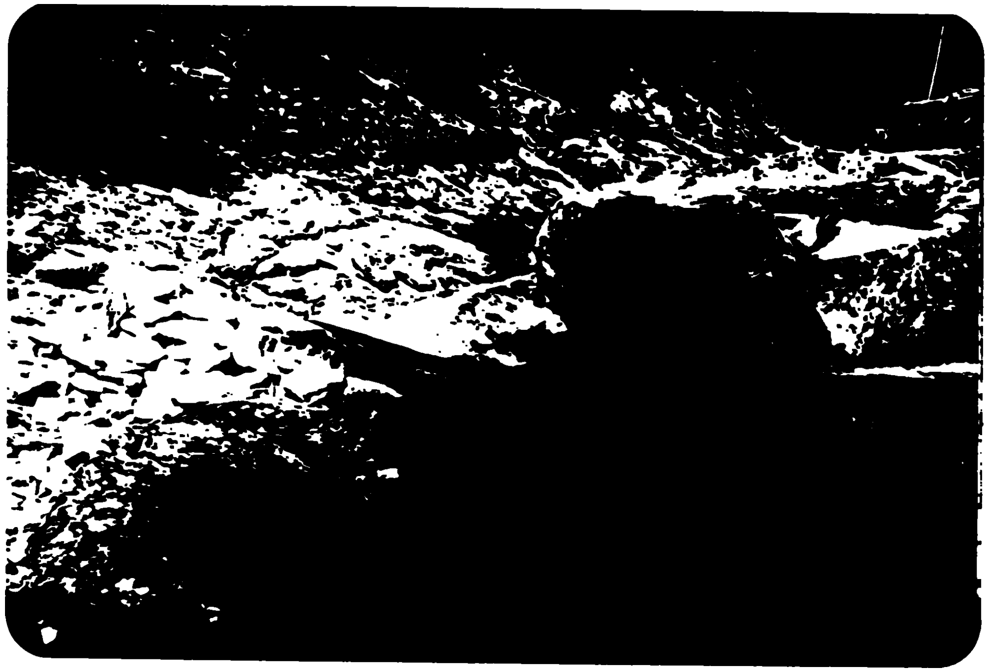


Figure 23. Post-blasting view of barrier No. 4--side channel.

Figure 24. Aerial view of barrier No. 3 and No. 4 (pre-blasting).

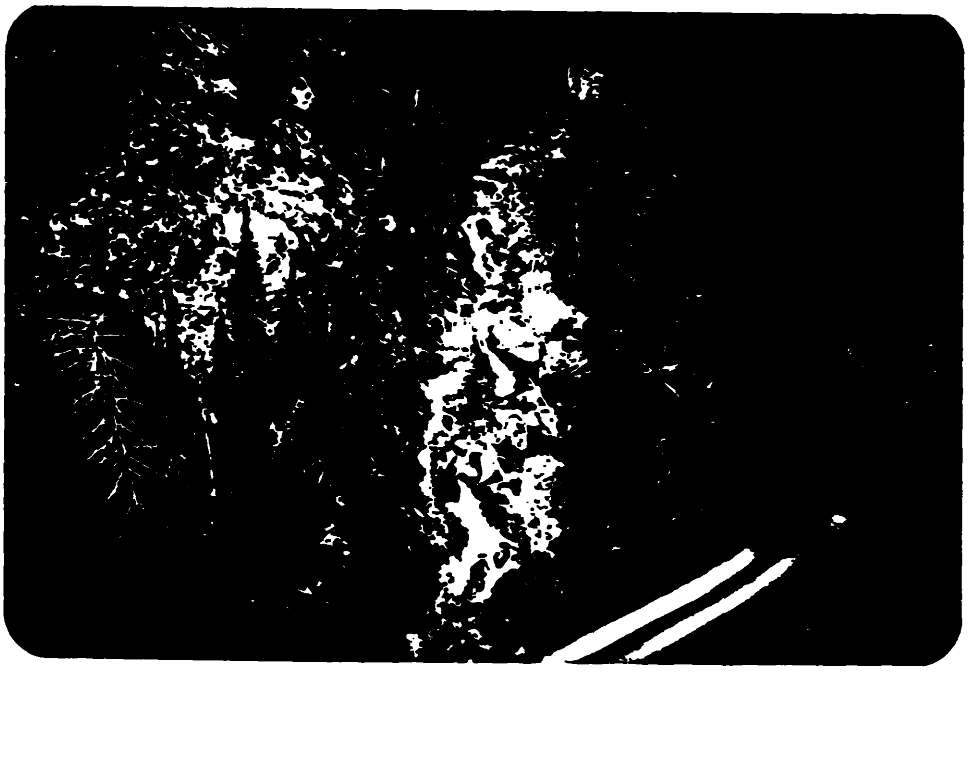


Figure 25 . Aerial view of barriers No. 3 and No. 4 (pre-blasting).

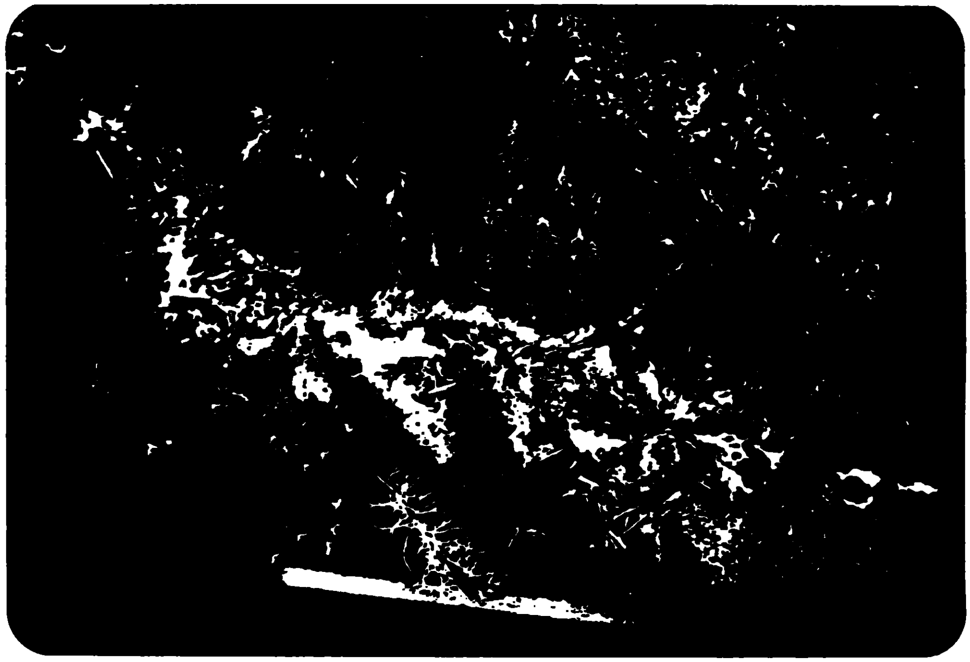


Figure 26 . Pre-blasting view of partial-barrier No. 5.

Figure 27. Post-blasting view of partial-barrier No. 5.

Figure 28. Post-blasting view of barrier No. 5.

Figure 29. Pre-blasting view of barrier No. 6.

Figure 30. Post-blasting view of barrier No. 6.

Figure 31. View of barrier No. 7 after the first blast.

Figure 32. Post-blasting view of barrier No. 7.

Figure 33. Aerial View of Barrier No. 7.

Figure 34. Pre-blasting View of Barrier No. 7.

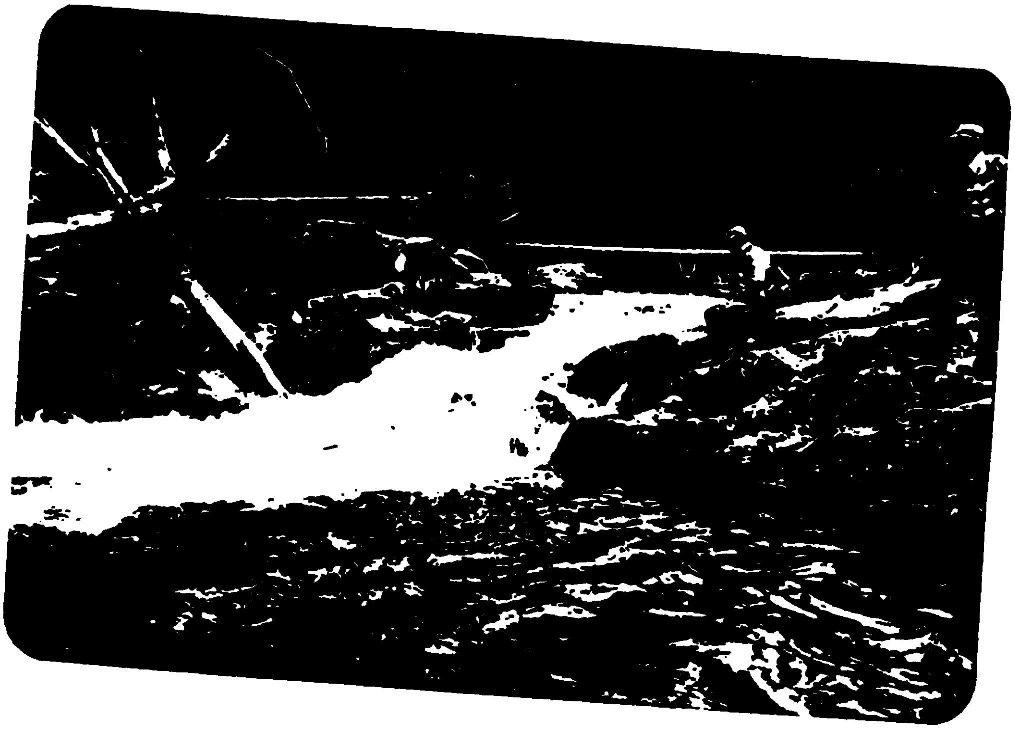


Figure 35. Pre-blasting view of parital-barrier No. 7A (upper end).

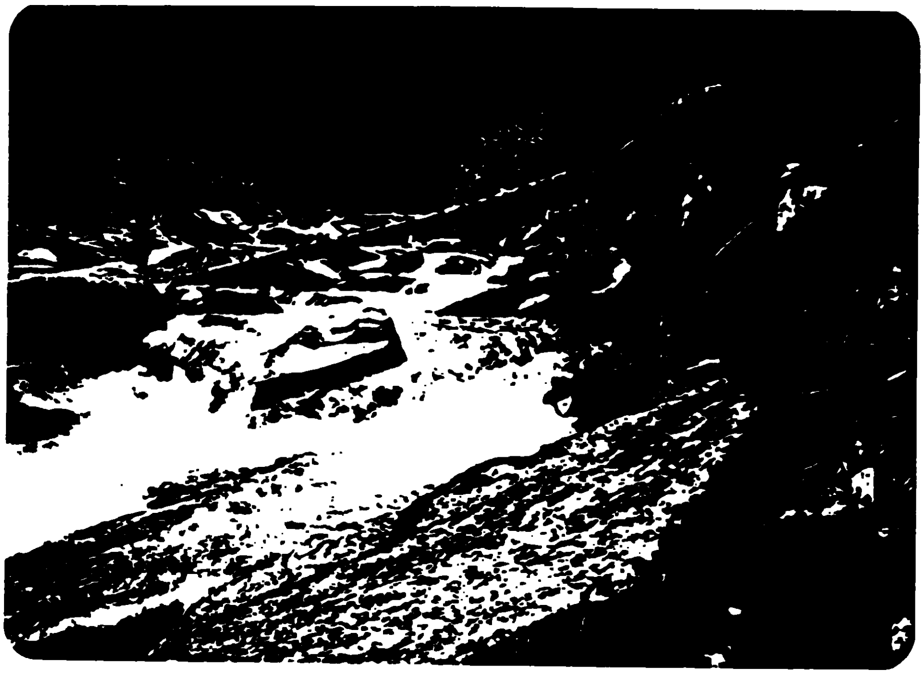


Figure 36. Post-blasting view of partial-barrier No. 7A (upper end).

Figure 37. Pre-blasting view of partial-barrier No. 7A.

ACKNOWLEDGEMENTS

Special thanks is given to Pat Murphy and Jeff Butler, without their help the completion of this project would not have been possible. Burt Currence, our blaster, deserves special recognition for completing this project in a safe and professional manner.

I would also like to thank Al Espinosa for his guidance throughout this project.

APPENDICES

Appendix A: Summary of Expenditures

Appendix B: Correction of Fish Passage Report by J.F. Orsborn.

APPENDIX A

Summary of Expenditures

Salaries	8,366.95
Nonexpendable Equipment and Material	--------
Expendable Equipment and Material	3,344.15
Operations and Maintenance	4,570.00
Overhead	3,124.00
Total	$20,006.00

APPENDIX B

Report on

CORRECTION OF FISH PASSAGE BARRIERS ON ELDORADO CREEK AND CROOKED FORK

—

CLEARWATER NATL. FOREST

—

Prepared for

AL ESPINOSA, Project Leader
12730 HIGHWAY 12
OROFINO, ID 83544

Prepared by

JOHN F. ORSBORN, P.E.
NW 420 MARYLAND CT.
PULLMAN, WA 99163

Work Conducted Under

PURCHASE ORDER No.
43-0276-4-0361 (6/4/84)

AUGUST 7, 1984

PART 1. FOUR BARRIERS ON ELDORADO CREEK;

PART 2. BARRIERS ON CROOKED FORK OF THE LOCHSA RIVER NEAR POWELL, IDAHO.

DESIGNS PROVIDED IN THE FIELD 8/1/84.

CROOKED FORK

These barrier sites consist mostly of sloping layers of bedrock which cause depth and velocity barriers for Chinook during lower flows in July and August.

In addition, many of the barriers provided poor jumping conditions at their bases because: (1) the jets splash on rocks and are diffused; (2) the jets strike the pool at a flat angle which disorients leaping fish; or (3) no adequate pool is available from which to leap.

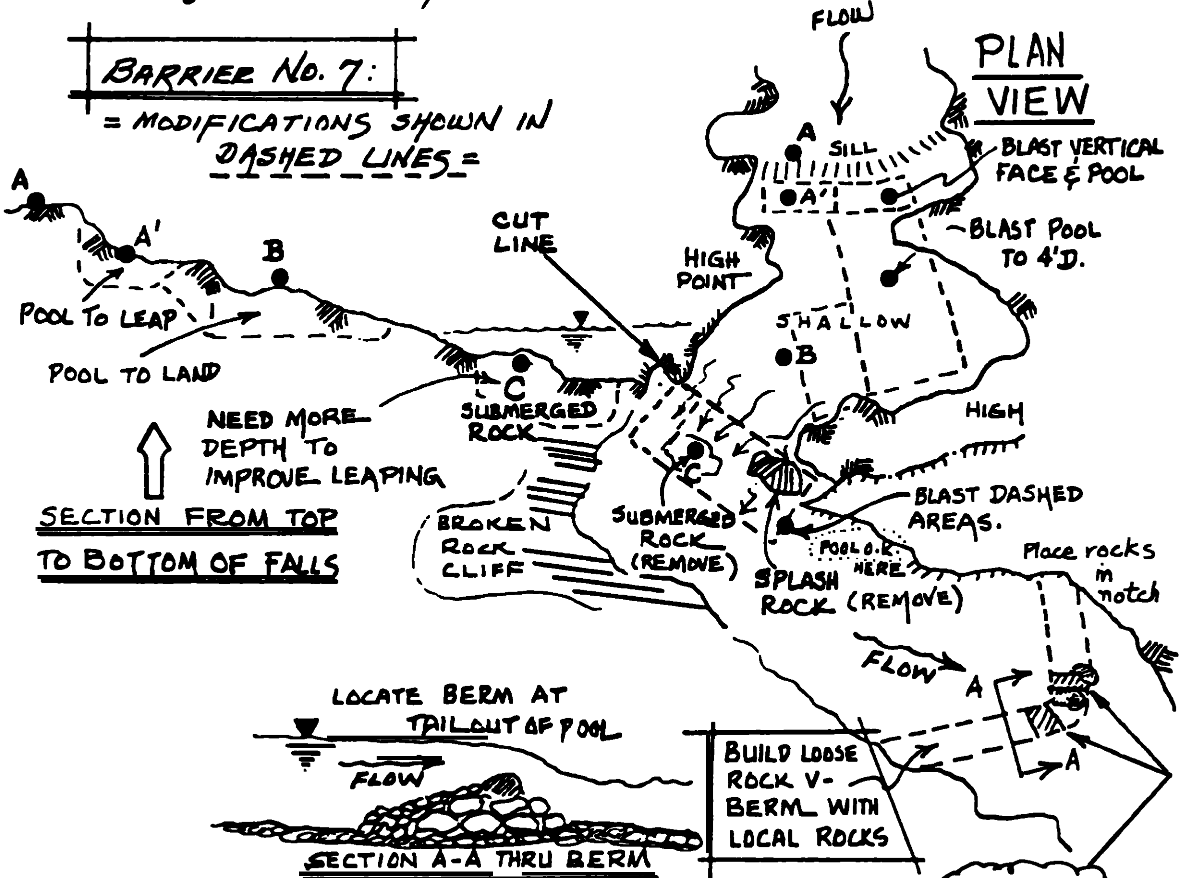
Large boulders and irregular rock structure complicated many of the passage problems by: (1) not providing adequate landing conditions for leaping fish; (2) causing discontinuous flow paths of adequate depth to negotiate high velocities; and (3) providing unstable conditions for modifying the barrier (some solutions may have developed into other passage barriers.

The sites on Crooked Fork were visited on 8/1/84. Late departure by helicopter only allowed enough time to visit 5 or the 7 designated barriers (Nos. 7-3 starting at the downstream end). Barriers 1 & 2 were observed from the air during the return flight to Powell Ranger Station.

As the site investigation team progressed upstream from the lowest barrier (No. 7), each barrier was discussed, alternative solutions were considered and recommended modifications were marked and noted in field books. Numerous smaller and less obvious barriers were noted, discussed and marked for correction besides the major barriers Nos. 3-7. Also, initial modifications of the barriers sometimes necessitated upstream modifications in the channels to match the flow patterns with the flow path of the modified barrier.

Eldorado Creek & Crooked Fork Barriers 11/13

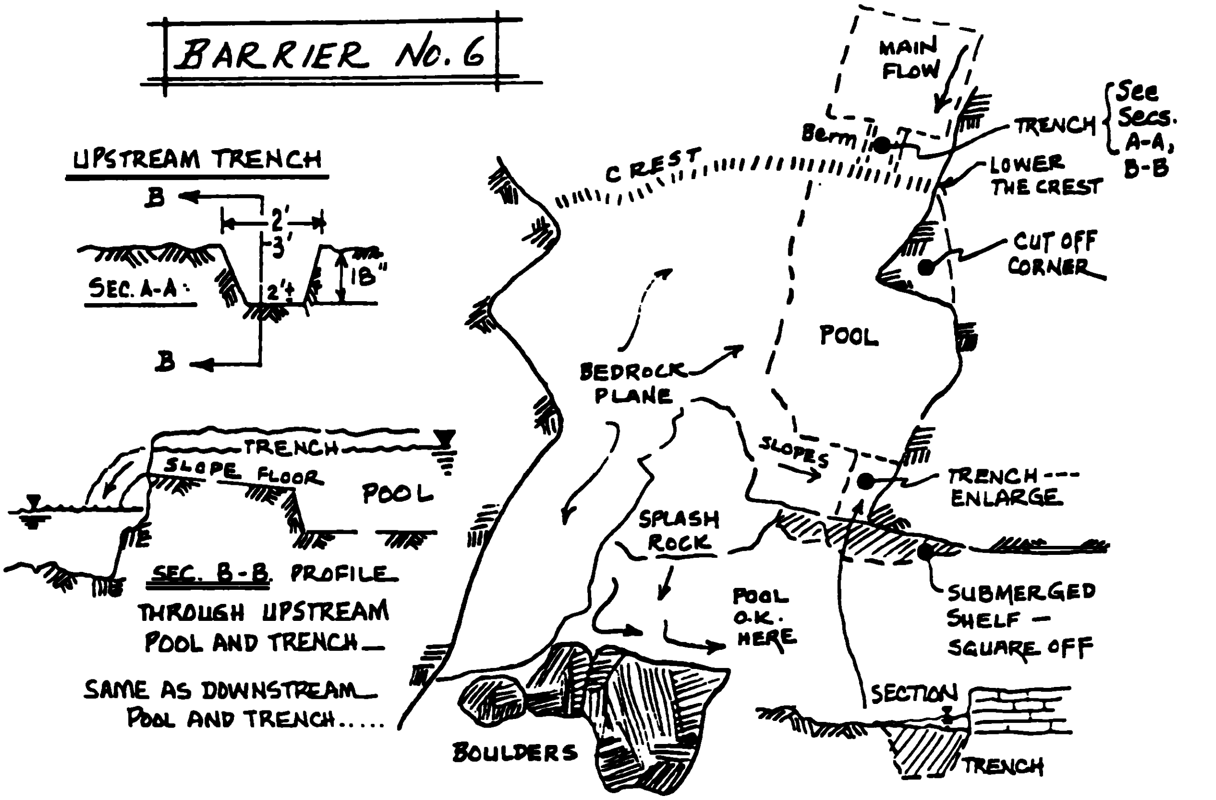
A summary analysis of each of the barriers visited is presented with a plan view sketch and sectional view(s) showing areas which should be excavated or modified in order to assist Chinook past these barriers during lower flow periods.



Beginning at the downstream end of the pool, the following modifications should be made to improve passage conditions at Barrier No. 7:

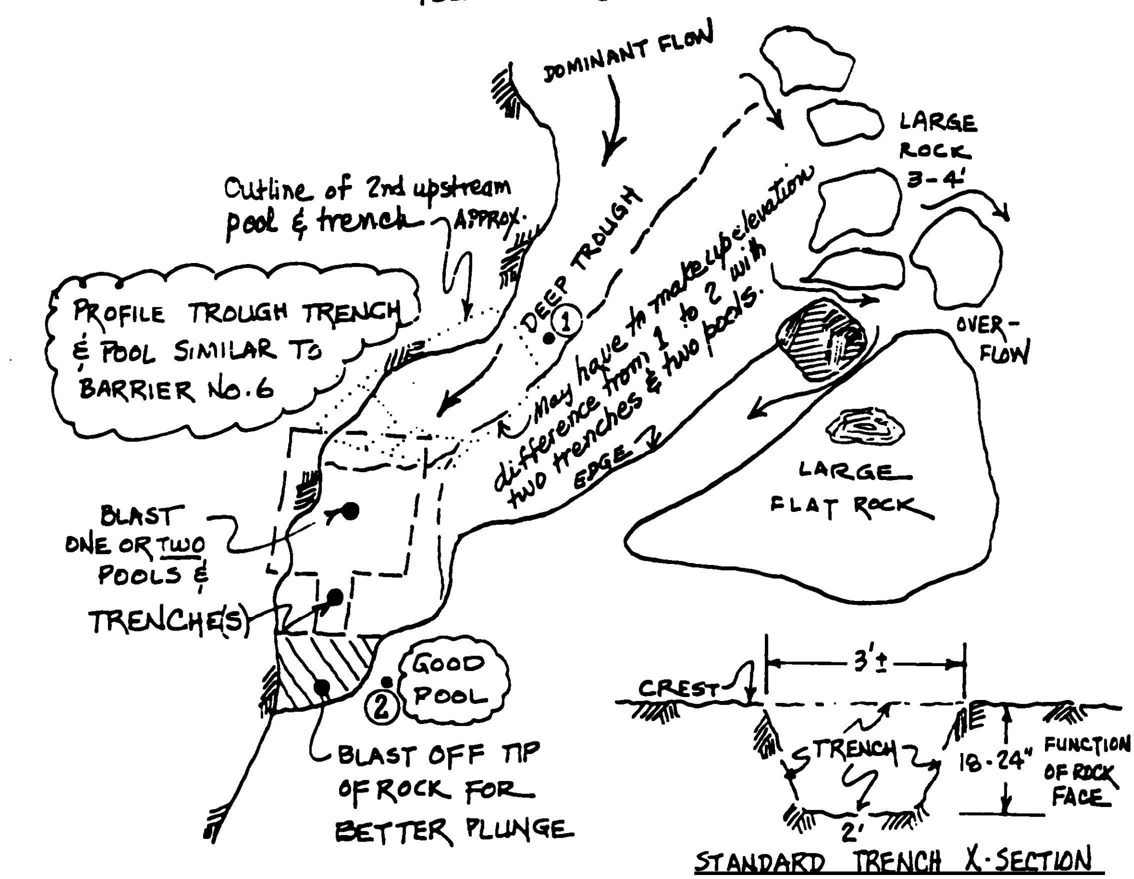
LOCATION	CHANGE	REASON	LOCATION	CHANGE	REASON
C - SPLASH BED-ROCK(S) AT BASE OF FALLS AND SLOPING FACE.	CUT AWAY ALONG CUT LINE ON RT. BANK	PROVIDE BETTER JUMP ANGLE & POOL.	B - A'	EXCAVATE POOL	REST AND LEAP POOL ALONG LEFT SIDE AND ACROSS FACE TO A'.
BUILD LOOSE ROCK BERM AT CHANGE IN GRADE.	RAISE POOL	REDUCE DROP IN FALLS BY 1 FT ±. INCREASE POOL DEPTH.	A'	CUT FACE VERTICAL	TO PROVIDE EASIER LEAP TO A.
			Cascade just above Barrier No. 7	Cut off long yellow finger of rock and enlarge pool on left side.	Improve leaping. 
B - TOP OF FIRST (LOWER) FALLS	EXCAVATE POOL TO 4'	PROVIDE DEEP LANDING			

BARRIER No. 6



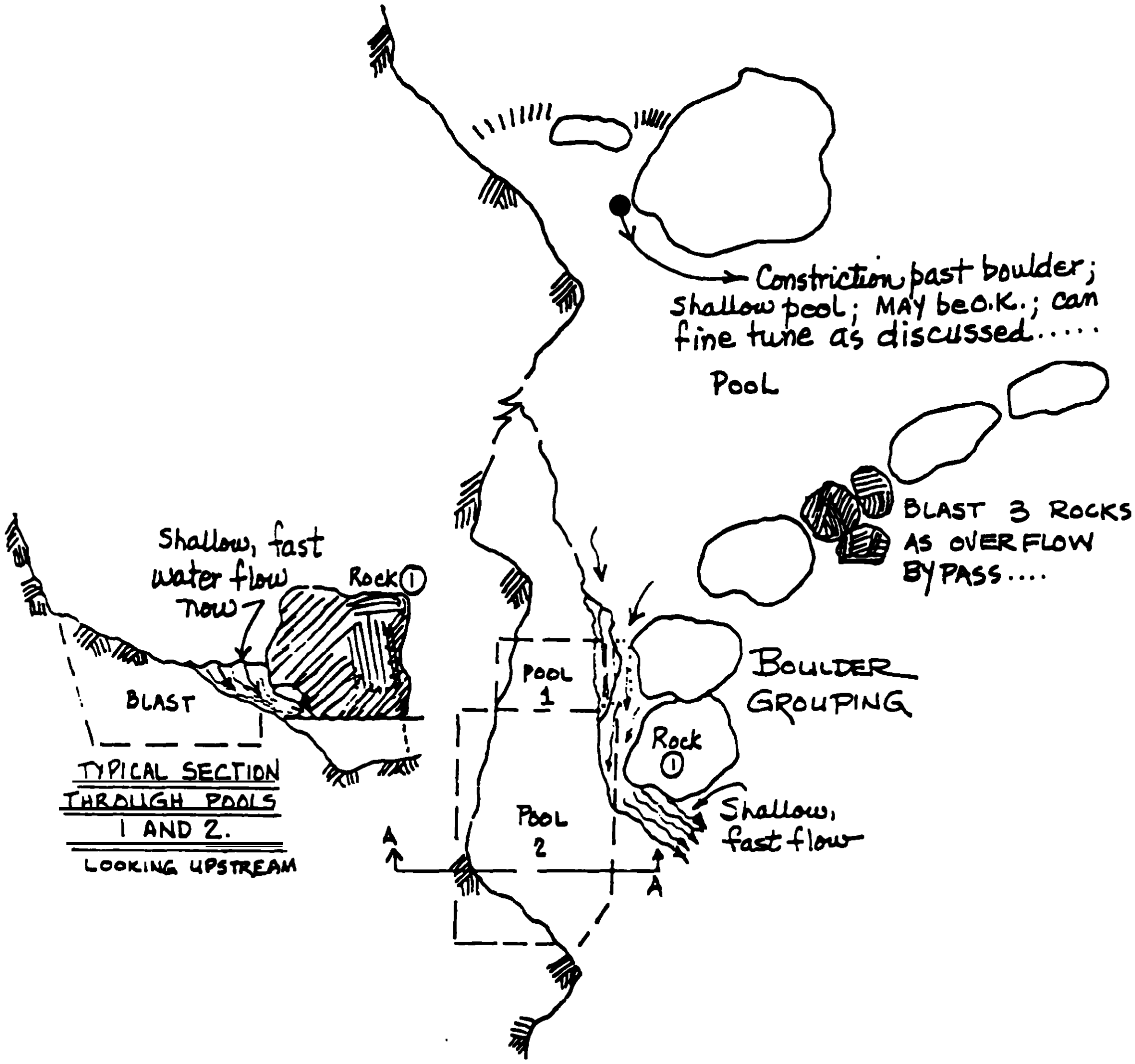
BARRIER No. 5

DIAGONAL CHUTE WITH LARGE TRIANGULAR TABLE ROCK ON LEFT –



BARRIER NO. 4

LOWER BOULDER GROUPING
— AND —
UPSTREAM CHUTE
AROUND LARGE BOULDER



Site No. 3 was documented and marked in place by the District biologist, as were numerous intermediate, lesser barriers.

Sites 1 & 2 were not visited on the ground, but were observed from the air and discussed as to the modifications to be made.

Slides of Barriers 4-7 are appended.

EVALUATION AND MAINTENANCE OF UPPER LOCHSA HABITAT ENHANCEMENT STRUCTURES

Powell Ranger District

Clearwater National Forest

Region 1

BPA Project *DE-AI79-84BP 16535

Columbia River Basin Fish and Wildlife Program

Northwest Power Planning Council

Northwest Power Act (P.L. *96-501)*

An Annual Report Submitted to the
Bonneville Power Administration

by

Richard P. Kramer
District Fisheries Biologist
Clearwater National Forest

F.A. Espinosa, Jr.
Forst Fisheries Biologist
Project Leader

TABLE OF CONTENTS

ABSTRACT

In 1983, and under the auspices of the NorthWest Power Act, the Clearwater National Forest and Bonneville Power Administration entered into a contractual agreement to improve anadromous fish habitat in three major tributaries of the Clearwater River in Idaho. Two of the streams enhanced were Crooked Fork Creek and White Sand Creek, tributaries to the Lochsa River on the Powell Ranger District.

The primary objectives of the 1984 project were to evaluate and maintain the structures. Severe ice jams in the spring of 1984 played a major role in the success of some of the structures.

Data was collected and analyzed to determine the physical differences in the structures one year after installation and the habitat changes.

It was virtually impossible to maintain structures that had been washed on the banks by ice flows but additional trees were felled to enhance existing structures.

Based on initial observations of structures which failed, several other experimental structures were installed. These structures will be monitored and compared to 1983 structures.

In our opinion, the structures installed in 1983 had a positive effect in enhancing the habitat in the two project streams and we felt that this technique has great promise in other streams where low cost and remote locations are a consideration. Further evaluation will have to be continued to determine their effect on fish populations.

INTRODUCTION

In 1983, and under the auspices of the NorthWest Power Act, the Clearwater National Forest and Bonneville Power Administration entered into a contractual agreement to improve anadromous fish habitat in three major tributaries of the Clearwater River in Idaho. Two of the streams enhanced were Crooked Fork Creek and White Sand Creek, tributaries to the Lochsa River on the Powell Ranger District (fig. 1).

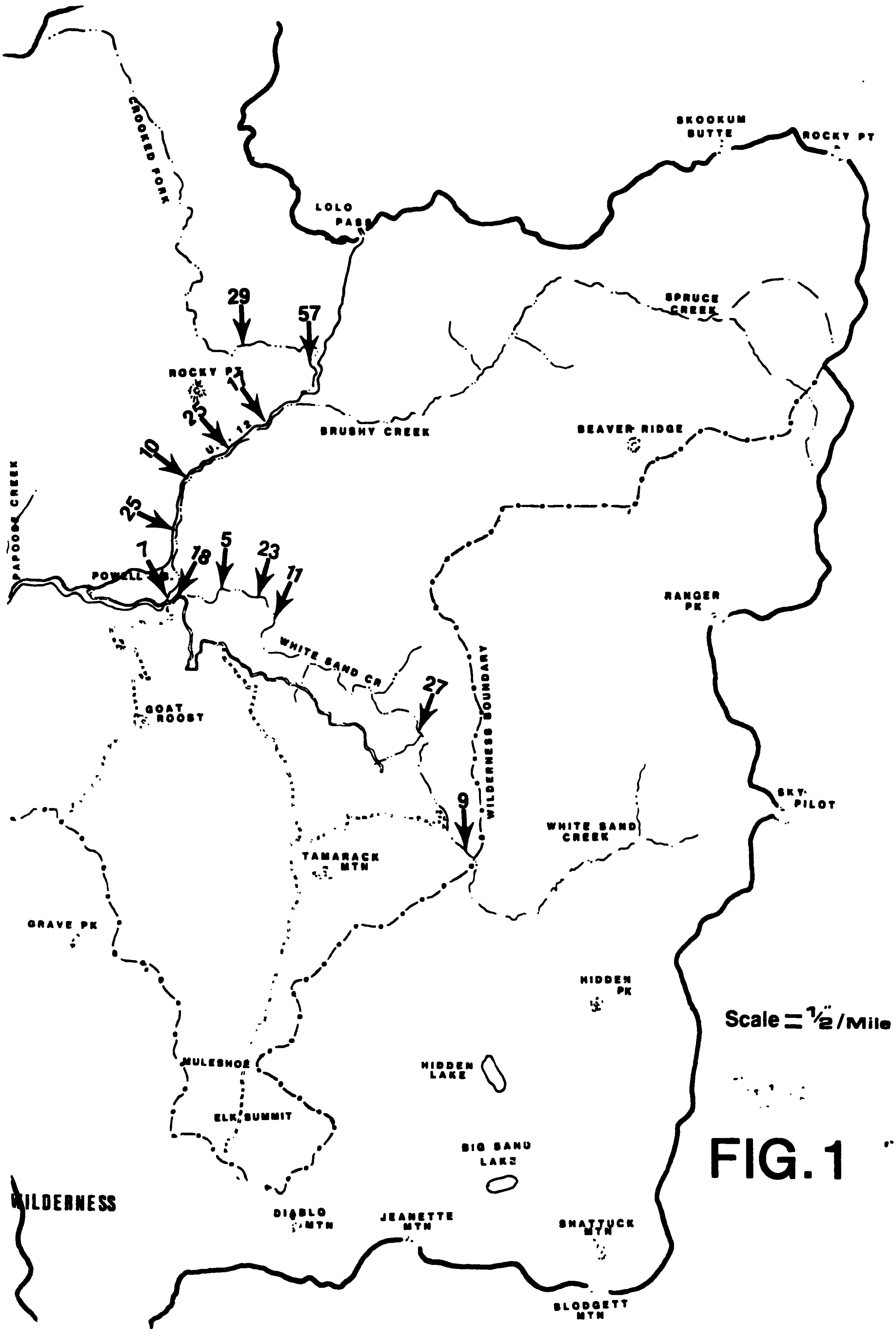
A total stream distance of 9.1 miles was enhanced on Project streams: seven reaches and a total of 5.65 miles on Crooked Fork; five reaches and 3.45 miles on White Sand (Espinosa 1984). The Project crew felled a total of 198 conifers with 120 going down in Crooked Fork and 78 in White Sand. In addition to felling riparian trees, existing debris that was enhancing the habitat was cabled to nearby anchor points. A total of 63 existing debris units were secured in both streams.

The primary objective of the 1984 Project was to evaluate and maintain the structures installed in 1983. The following report is a description of methodology, activities, results, and conclusions.

DESCRIPTION OF PROJECT AREA

The Clearwater National Forest (1.8 million acres) is located in north central Idaho and supports some of the most significant and valuable salmonid resources in the region (fig. 2). The Forest provides a total of 2,500 acres of spawning, rearing, and migratory habitats for two anadromous species - spring chinook salmon and summer steelhead trout. Of this total, 100 acres consist of high quality spawning habitat.

Recent history has documented the massive hydroelectric development of the Columbia and Snake Rivers and their major tributaries. This development has been costly in terms of the basin's and Forest's fish resources. In 1927, a dam built near Lewiston, Idaho virtually destroyed the run of spring chinook salmon in the Clearwater River drainage. In the early 1970's Dworshak Dam on the North Fork of the Clearwater River eliminated 60 percent of the Forest's highest quality habitat for steelhead trout; and Lower Granite Dam on the Snake River increased the mortality gauntlet to a total of eight dams on the system that fish destined for Idaho or the ocean had to negotiate. By the mid 1970's, Idaho stocks of anadromous fish had bottomed out and were perched on the brink of extinction. Since that time, accelerated efforts of mitigation and restoration have actuated a trend of significant recovery - especially for steelhead trout.



CROOKED FORK
LOLO PASS
SKOOKUM BUTTE
ROCKY PT
SPRUCE CREEK
29
57
ROCKY PT
17
2
U. 12
BRUSHY CREEK
BEAVER RIDGE
10
PAPOOSE CREEK
25
7
18
5
23
11
POWELL
WHITE SAND CR
RANGER PK
GOAT ROOST
27
WILDERNESS BOUNDARY
9
SKY PILOT
WHITE SAND CREEK
TAMARACK MTN
GRAVE PK
HIDDEN PK
Scale = 1/2"/Mile
MULESHOE
HIDDEN LAKE
ELK SUMMIT
BIG SAND LAKE
WILDERNESS
DIABLO MTN
JEANETTE MTN
SHATTUCK MTN
BLODGETT MTN

FIG.1

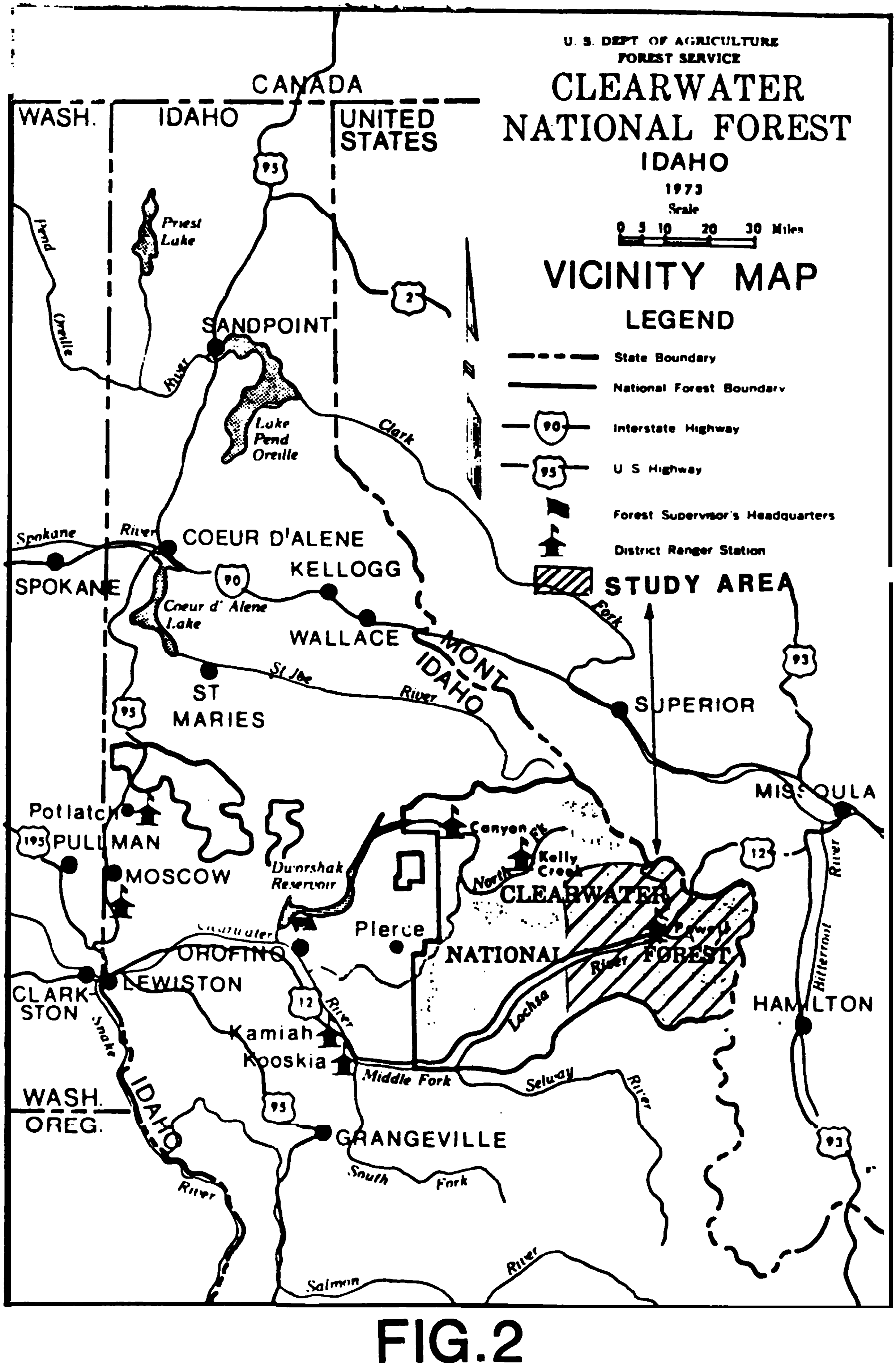

U. S. DEPT OF AGRICULTURE
FOREST SERVICE
CLEARWATER
NATIONAL FOREST
IDAHO
1973
Scale
0 5 10 20 30 Miles
VICINITY MAP
LEGEND
State Boundary
National Forest Boundary
Interstate Highway
U S Highway
Forest Supervisor's Headquarters
District Ranger Station
STUDY AREA
CANADA
WASH.
IDAHO
UNITED STATES
Priest Lake
Pend Oreille River
SANDPOINT
Lake Pend Oreille
Clark Fork
Spokane River
COEUR D'ALENE
SPOKANE
KELLOGG
Coeur d' Alene Lake
WALLACE
MONT
IDAHO
ST MARIES
St Joe River
SUPERIOR
MISSOULA
Potlatch
PULLMAN
MOSCOW
Dworshak Reservoir
Canyon
North Fk
Kelly Creek
CLEARWATER
NATIONAL FOREST
Powell
Pierce
OROFINO
Lochsa River
LEWISTON
CLARKSTON
Kamiah
Kooskia
Middle Fork
Selway River
HAMILTON
Bitterroot River
WASH.
OREG.
IDAHO
Snake River
GRANGEVILLE
South Fork
Salmon River
90
95
93
12
195
2

FIG.2

Three of the most significant producers of anadromous fish among the basin's tributaries are Lolo, Crooked Fork, and White Sand Creeks. Crooked Fork and White Sand Creeks are the principal producers of the Lochsa River system (upper Clearwater River). Under optimum habitat and escapement conditions - Lolo, Crooked Fork, and White Sand Creeks are capable of producing 33 percent of the total steelhead and 44 percent of the total salmon smolt production on the Forest.

Crooked Fork and White Sand Creeks reach confluence near Powell, Idaho (3500 feet elevation) to form the Lochsa River (figs. 1 and 2). Both streams are in fact small rivers with each draining approximately 150,000 acres of the Bitterroot Mountains and coursing some 24 miles to their merger.

Both streams are characterized by a flow regime of wide amplitude. Crooked Fork displays a mean discharge of 3000 c.f.s. during the peak run-off period and 150 c.f.s. during the late summer, base flow; whereas, White Sand exhibits an average flow of 3000 c.f.s. during peak run-off and 170 c.f.s. at base flows. Within the project area, Crooked Fork shows a mean stream width and depth of 34 feet and 1.1 feet respectively (base flows); while White Sand displays a mean width and depth of 86 feet and 0.8 feet. Both systems are characterized by similar channel gradients with a mean of 1.0 percent and a range of 0.5 percent to 2 percent.

The Project streams drain a variety of landforms that include glacial, valley trains, steep breaklands, colluvial drift slopes, and alluvial flood plains. Breaklands and alluvial plains dominate their watersheds. Granitic soils of the Idaho Batholith typify the geology of the area. The streams flow through dense, mixed coniferous stands of western red cedar, Douglas-fir, Englemann spruce, white pine, ponderosa pine, and larch. Few deciduous species are present within the riparian zones.

Crooked Fork has experienced *extensive* timber harvesting and road construction for the past two decades. Most of this activity has been concentrated in its lower reaches and in the Brushy Fork subdrainage. Impacts associated with sedimentation and over-harvesting in the riparian *zones* have been moderate. The upper reaches of Crooked Fork are undeveloped *and* pristine. White Sand Creek has only been developed in its extreme lower reaches from Beaver Creek on downstream. Its Beaver Creek tributary has been extensively harvested and roaded. Impacts to White Sand Creek have been minimal, and it is essentially roadless and pristine.

Both watersheds are under the management of mixed ownership: the U.S. Forest Service and Plum Creek Timber Company. Crooked Fork is characterized by a checkerboard pattern with Plum Creek owning some 34,000 acres (23%). The Forest Service administers 98% of the White Sand watershed.

The headwaters of both drainages are located in either a wilderness candidate area (Crooked Fork, RARE II) or a designated wilderness (White Sand, Selway-Bitterroot Wilderness).

In 1979, an intensive habitat survey was completed on Crooked Fork Creek by Powell District personnel. Espinosa (1984) discussed the habitat analysis derived from the survey.

METHODS AND MATERIALS

The objectives of this project were twofold: 1) to evaluate the structures and 2) to maintain or enhance existing ones.

A two-man crew began collecting data and maintaining structures in July. Angles of trees with respect to the downstream bank, gradient of structure, and length of structure in the water were recorded and compared to data in 1983 to determine any movement of the structure. Habitat type (pool, riffle, run, and pocket water) and general substrate composition of the river in the area of the structure were recorded.

No pool habitat parameters were collected in 1983, but maximum pool depth, pool area, and cover rating were recorded in 1984. Although a comparison of change from 1983 to 1984 couldn't be made, this enabled us to determine the quality and quantity of habitat at each site and would allow continued monitoring throughout the life of the structures. The cover rating used was broken down into four categories. Specific definitions are:

0 - No cover provided

1 - Cover Light: Less than 1/4 of the pool perimeter or area has cover.

2 - Cover Moderate: 1/2 - 1/4 of perimeter or area of the pool has cover.

3 - Cover Abundant: More than 1/2 the perimeter or area of the pool has cover.

Description of the cables securing the structures were recorded to evaluate failures of the structures.

Data was compared to determine if tree size, habitat type, and location in stream meander had any effect of the success of the structure.

Habitat provided by the structures was defined in two different ways. All determinations were made at low flows. Trees that were actively scouring were differentiated from trees that were suspended above the water surface but still providing cover. It was felt that the trees not actually in the water were important from the stand point that they were providing overhead cover and would create pool habitat at higher flows when water was scouring around them.

Cables were replaced on structures that were still in place but had broken cables. A come-a-long and chainsaw winch were used in an attempt to pull trees back into the mainstem of the river where ice flows or high water flow had rendered them ineffective on the bank. Additional trees were felled wherever possible to enhance existing sites.

Based on initial observations on the success of the structures, several other types of structure were added to the streams to replace structures that had failed which included the following:

- Single log or groups of logs.
- Logs forming a jetty.
- Logs forming a downstream "V".
- Logs rebarred with 3/4" rebar.

Single logs or groups of logs were felled and cabled, only when at least 24" d.b.h. trees were available and, based on preanalysis the location would ensure the effectiveness and longevity of the structure. Location of additional structures was concentrated in side channels and other low velocity areas. All trees were felled at less than a 90° angle. All limbs were left on the trees.

Jetties were formed by dropping the upstream tree first and then a downstream tree (felled upstream on top of the first tree) (figs. 3-5). Trees were cabledto the stump and at the junction.

Two downstream "V"s were installed in side channels where the channel width was narrow enough to allow the falling of two trees on opposite banks downstream and intersecting each other - forming a downstream "V". Trees were cabled as usual and at the intersection.

Several large trees were felled in reaches at angles greater than 30°. Holes were bored into the trees and at least 4-8 ft lengths of 3/4" rebar were driven into the substrate (figs. 6-9) using a Pionjar rock drill. This method has been successful in maintaining structures in position on several streams on the Mt. Baker-Snoqualmie (Matt Longenbough, personal communication).

RESULTS AND DISCUSSION

Evaluation of Structures

Although the snow pack during the winter of 1983-84 was 70% of normal, winter temperatures were ideal for creating a heavy ice pack on the Crooked Fork and White Sand Creek (fig. 10). Ice jams as high as 8 ft on these streams had a serious effect on the effectiveness of some of the structures installed in the summer of 1983 (figs. 11 & 12). Ice jams may be a continuing problem for this type of structure but according to long time residents of Powell, the ice jams during the spring of 1984 were the biggest observed in five years. Generally these jams are on the Lochsa River itself not on its tributaries.

Of the 261 structures, including existing debris structures and live trees, only 17 structures or 7% were completely removed from there anchor points. Existing debris had only a slightly higher breakage rate (8% vs 6%) (Table 1).

Figure 3 . Jetty structure installed in White Sand Creek, Twin Bridges Reach, Site #10, 1984.

Figure 4 . Jetty structure installed in White Sand Creek, Twin Bridges Reach, Site #9, 1984.

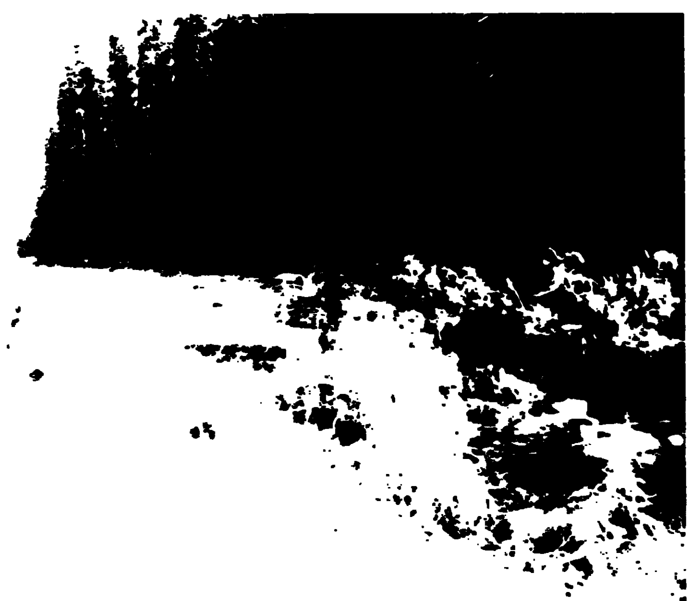


Figure [illegible]. Jetty structure installed in White Sand Creek, Twin Bridges Reach, Site [illegible]7, 1984. Taken in late fall, note ice beginning to form on [illegible].

Figure 6. Boring hole into downed tree before drilling rebar into the substrate, White Sand Creek, 1984.

Figure 7. Drilling rebar into tree with use of Pionjar drill.

Figure 8 . Drilling rebar into tree with use of Pionjar drill.

Figure 9 . Bending rebar over after drilling approximately seven feet into substrite.

Figure 10. Ice jam on Crooked Fork Creek during spring of 1984.

Figure 11. Ice damage to live debris structure on Crooked Fork Creek.

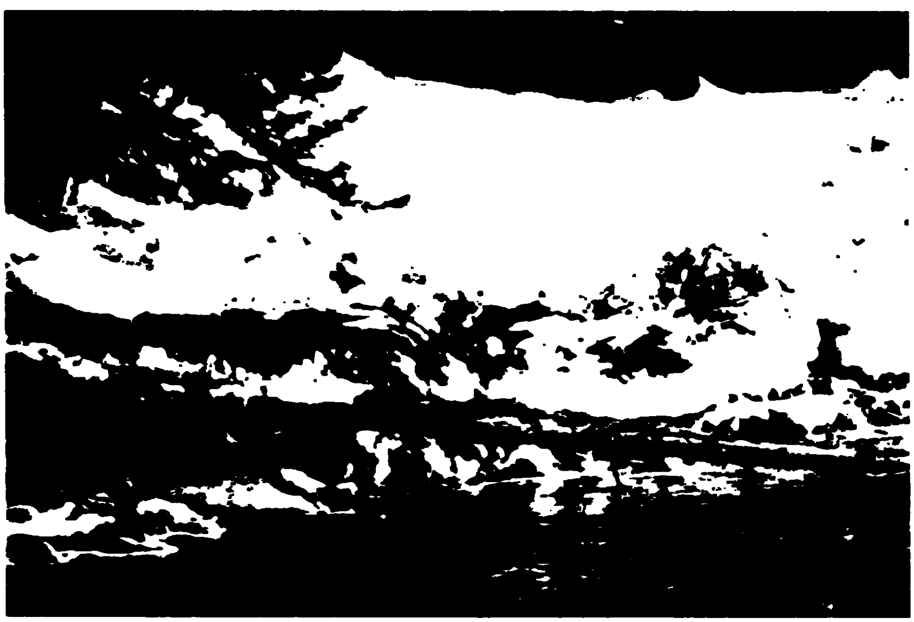


Figure 12.-- [illegible] structure during ice flow on Crooked Fork Creek, 1934.

Table 1. Comparison of organic debris with broken cables or rendered ineffective one year after installation in Crooked Fork Creek and White Sand Creek, 1984.

	LIVE TREES					EXISTING DEBRIS				
Stream	No. Trees Felled	No. With Broken Cables	Percent	No. Moved On Bank	Percent	No. Structures	No. With Broken Cables	Percent	No. Moved On Bank	Percent
Crooked Fork	120	11	1	17	14	48	4	8	1	1
White Sand	78	1	9	17	21	15	1	6	1	6
TOTAL	198	12	6	34	17	63	5	8	2	3

A total of 35 or 18% of the structures were physically moved totally on the stream bank rendering them ineffective (figs. 13-15). Live trees were moved onto the stream bank more than existing debris, 17% vs 3%. This is presumably due to the fact that at the time of cabling, the existing debris was more stable because of its being in the system for more than one season.

Total failure rate for both existing debris and live trees was 20%. Overall failure rates on White Sand Creek and Crooked Fork Creek were essentially the same (22% vs 20%), but tree movement onto the bank in White Sand was 7% higher than Crooked Fork (Table 1).

Although trees washed up on the bank have no opportunities of providing habitat in the stream, it can be assumed that some of the trees with broken cables are still in the system providing habitat. Generally, trees themselves broke before the cables broke.

A total of 65 trees were actively scouring one year after installation and an additional 76 were providing cover but were suspended above the waters surface (Table 2). Overall 71% of the trees installed were providing some type of habitat. The effectiveness of existing debris remained high, 59% (37 of 63) were still actively scouring and 24% (15 of 63) were suspended. Again, the increased success of the existing debris can be attributed to increased stability over live trees at the time of securing with cable. Another factor affecting the difference in live trees and existing debris is the fact that only existing debris that was providing habitat was secured while it was impossible to fall every tree successfully to insure it would provide fish habitat over a period of time. The total number of structures providing habitat with live trees and existing debris combined was 193 out of 261 installed or 74%. Structures scouring represented 39% of the total.

Structures actively scouring had a high mean cover quality and a greater amount of pool habitat per structure. A total of 10,856 sq ft of pool habitat was created by the live trees and 4763 of pool habitat by the existing debris (Table 3). Mean depths of the pools were slightly higher for existing debris structure (1.29 ft vs 1.10) (Table 3).

Distribution of Class I, II, and III cover was evenly distributed in structures created by live trees (33%, 38%, and 29% respectively) but pools created by existing debris were predominantly Class II cover (58%) with only 6% of the pools with Class III cover (Table 3).

Live structures produced an average of 54 ft^2 of pool habitat per structure overall and existing debris structure produced an average of 75 ft^2 of pool habitat per structure. White Sand Creek consistently produced more pool habitat per structure than Crooked Fork in both live trees and existing debris (67 ft^2/structure vs 45 ft^2/structure for live trees and 105 ft^2/structure vs 66 ft^2/structures for existing debris). No explanation can be given for this difference.

Figure 13 . Live tree felled in Crooked Fork Creek, Twin Bridges Reach, Site #2, 1983.

Figure 14 . Live tree felled in Crooked Fork Creek, Twin Bridges Reach, Site #2, one year after installation, 1984.

Figure [illegible]. Live tree felled in White Sand Creek one year after installation, 1984. Structure rendered ineffective by iceflows.

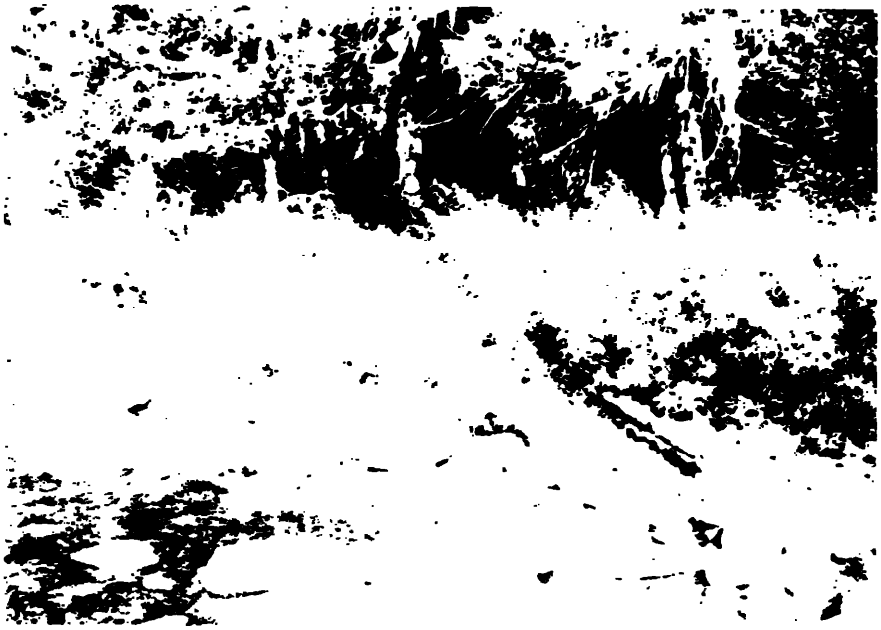


Table 2. Comparison of organic debris providing habitat one year after installation, by reach; in Crooked Fork Creek and White Sand Creek, Idaho, 1984.

	Live Trees			Existing Debris		
Reach	Number of Trees Felled	Number Actively Scouring	Number Suspended	Number of Existing Debris	Number Actively Scouring	Number Suspended
			Crooked Fork Creek			
T.B.	7	2	2	0	0	0
D.R.	17	9	3	8	8	0
R.A.D.	3	0	0	7	6	1
3/4 S.	13	5	4	3	3	0
HWY 12B	24	2	14	0	0	0
HWY 12A	33	11	13	24	8	7
Ford	23	8	9	6	3	3
TOTAL	120	37	45	48	28	11
			White Sand Creek			
T.B.	12	5	5	6	4	2
C.R.	5	1	2	0	0	0
C.C.R.	21	7	10	2	2	0
B.C.R.	11	4	6	0	0	0
C.C.C.R.	29	11	8	7	3	2
TOTAL	78	28	31	15	9	4
GRAND TOTAL	198	65	76	63	37	15

Table 3. Square feet of pool habitat created by type of structure, pool class, and mean of maximum depths in Crooked Fork and White Sand Creek, 1984.

Stream	Type of Structure	Number of Sites	Area of Pool Habitat by Cover Class (sq ft) I	II	III	TOTAL	Mean of Maximum Depth ft.
Crooked Fork	Live	120	1740	1958	1766	5464	0.98
White Sand	Live	78	1815	2076	1301	5192	1.27
TOTAL	Live	198	3555	4034	3067	10656	1.10
Crooked Fork	Existing Debris	48	547	2323	306	3176	.34
White Sand	Existing Debris	15	1122	465	---	1587	1.19
TOTAL	Existing Debris	63	1669	2788	306	4763	1.29

Although structures not in the water were obviously providing cover but at higher flows they theoretically should be scouring and over time produce a pool. Table 4 displays the amount of pool habitat created by the two types of structures. There was a considerable amount of variability between structures but structures in the water consistently produce more pool habitat. Comparing existing debris structures out of the water to live structures out of the water gives some indication that live structures will continue to develop more pool habitat over time as long as they are stable.

Data indicates that 38% of the trees showed some type of change whether by change in angle or change in length from being broken off (figs. 16-23). This includes trees totally washed up on the banks. But when comparing actual angles of trees installed in 1983 vs the remaining structures in 1984, little change is evident. Approximately 81% of the live trees installed in 1983 were at angles greater than 30° and 92% of live trees were at angles greater than 30° in 1984. Existing debris behaved similarly, 42% of the structures were > 30° in 1983 and 38% were > 30° in 1984.

There were no striking differences in angles producing functioning structures overall (actively scouring and suspended combined), the range was 71% to 100% (Table 5) with the 100% coming from only five existing debris structures on the Crooked Fork which were at angles between 20°-30°.

Tree size was compared to see if it had any influence on the effectiveness (actively scouring and suspended combined) of the structures (Table 5). Trees greater than 24" d.b.h. installed as existing debris were 95% effective with 81% of these structures actively scouring at the time of the survey. Live trees actively scouring in either size category showed little difference in effectiveness (34% for trees < 24" d.b.h. vs 30% for trees > 24" d.b.h.). Overall effectiveness of both large and small trees was similar (72% for trees < 24" d.b.h. vs. 70% for trees > 24" d.b.h.).

Overall, larger tree size had an increased effect on the amount of habitat created (Table 6). Live structures created from logs greater than 24" d.b.h. created over two times as much habitat. Existing debris did not show as much increase by tree size and also had a great amount of variability.

Structures were compared to determine if the habitat type that the structure was placed in had any effect on its effectiveness (Table 7). Three habitat types were delineated: pool, riffle, and run.

Existing debris placed in pools and runs had a 100% effectiveness rate and the majority of the structures were actively scouring (Table 7). This may be expected since the depths in both of these habitat types are deeper than in a riffle type and therefore it is physically easier for the trees to sink to a level that it can scour. In many cases, trees that were felled in riffle sections were supported by boulders above the waters surface at low flows.

Live trees had a higher rate of overall effectiveness when felled in pool habitat (75% vs. 67% for riffle and 68% for runs). Live trees also showed a higher incident of actively scouring in pool habitat (48% vs. 25% for riffle and 29% for runs.

Table 4. Comparison of pool habitat created per structure by type of habitat effectiveness in Crooked Fork and White Sand Creek.

STREAM	TYPE OF STRUCTURE	FT^2 OF HABITAT PER STRUCTURE ACTIVELY SCOURING		FT^2 OF HABITAT PER STRUCTURE SUSPENDED	
Crooked Fork	Live tree	114	n=37	25	n=45
White Sand	Live tree	115	n=38	40	n=31
Total	Live tree	114		31	
Crooked Fork	Existing Debris	103	n=28	29	n=11
White Sand	Existing Debris	151	n=9	235	n=4
Total	Existing Debris	115		84	

Figure 16. Existing debris structure, secured in place with cables, 1983 in Crooked Fork Creek, Ford Reach, Site #6.

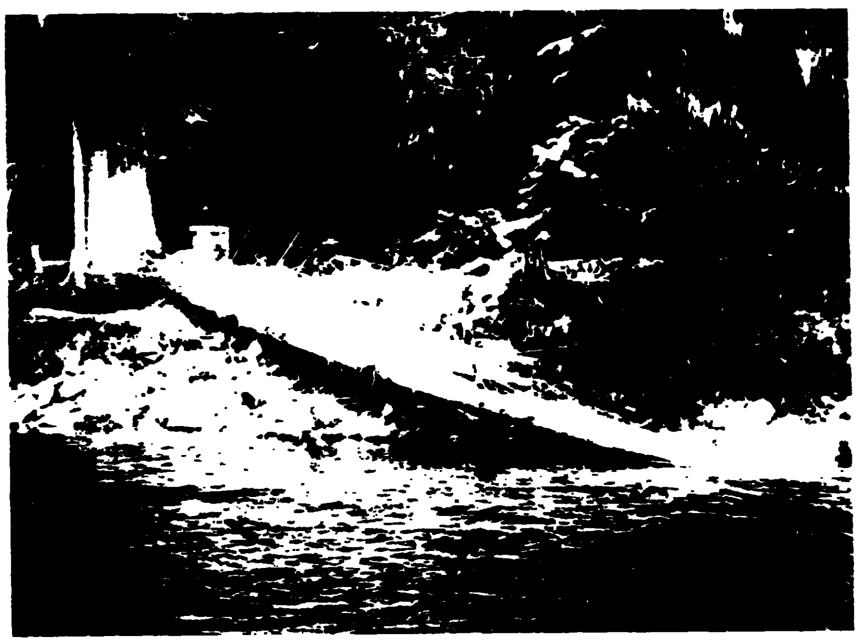
Figure 17. Existing debris structure, Crooked Fork Creek, Ford Reach Site #6, one year after installation 1984.

Figure 18. Existing debris structure secured in 1983 in Crooked Fork Creek, Devoto Reach, Site #12.

Figure 19. Existing debris structure, Crooked Fork Creek, Devoto Reach, Site #12, one year after installation, 1984.

Figure 20. Live trees felled in Crooked Fork Creek, Devoto Reach, Site #7, 1983.

Figure 21. Live trees felled in Crooked Fork Creek, Devoto Reach, Site #7, one year after installation, 1984.



[illegible] felled in Crooked Fork Creek, 3/4 Reach, Site #8, 1983.

Figure 23 . Live tree felled in Crooked Fork Creek 3/4 Reach, Site #8, one year after installation, 1984.

Table 5. Comparison of organic debris providing habitat one year after installation by angle in stream in Crooked Fork and White Sand Creek 1984.

Stream	Type of Structure	Angle	No. of Structures	No. Actively Scoring	Percent	Number Suspended	Percent	Total Providing Habitat	Percent
Crooked Fork	Live	<20°	3	1	33	1	33	2	67
White Sand	Live	<20°	6	1	17	4	66	5	83
TOTAL	Live	<20°	9	2	22	5	56	7	78
Crooked Fork	Live	20°-30°	4	3	75	-	—	3	75
White Sand	Live	20°-30°	1	-	—	1	100	1	100
TOTAL	Live	20°-30°	5	3	60	1	100	4	80
Crooked Fork	Live	>30°	114	33	29	44	38	77	67
White Sand	Live	>30°	70	27	38	26	37	53	75
TOTAL	Live	>30°	184	60	33	70	38	130	71
Crooked Fork	Existing Debris	>30°	30	17	57	8	27	25	83
White Sand	Existing Debris	>30°	4	3	75	~~1~~	~~25~~	4	100
TOTAL	Existing Debris	>30°	34	20	59	9	26	29	85
Crooked Fork	Existing Debris	20°-30°	5	4	80	1	10	5	100
White Sand	Existing Debris	20°-30°	—	—	—	-	—	—	—
TOTAL	Existing Debris	20°-30°	5	4	80	1	20	5	100
Crooked Fork	Existing Debris	>30°	13	7	54	2	15	9	69
White Sand	Existing Debris	>30°	11	6	54	3	27	9	81
TOTAL	Existing Debris	>30°	24	13	54	5	21	18	75

Table 6 . Comparison of organic debris providing habitat one year after installation by tree size in Crooked Fork and White Sand Creek, 1984.

Stream	Type Of Structure	Tree Size	Number of Structures	Number Actively Scouring	Percent Of Total	Number Suspended	Percent	Total Providing Habitat	Percent of Total	Ft^2 Pool Habitat Per Structure
Crooked Fork	Live	<24" DBH	81	27	33	27	33	54	67	29
White Sand	Live	<24" DBH	44	16	36	20	45	36	82	43
TOTAL	Live	<24" DBH	125	43	34	47	38	90	72	34
Crooked Fork	Live	>24" DBH	39	10	26	18	46	28	72	76
White Sand	Live	>24" DBH	34	12	35	11	32	23	68	76
TOTAL	Live	>24" DBH	73	22	30	29	40	51	70	76
Crooked For	Existing Debris	<24" DBH	30	13	43	9	30	22	73	45
White Sand	Existing Debris	<24" DBH	12	7	58	3	25	10	83	176
TOTAL	Existing Debris	<24" DBH	42	20	48	12	29	32	76	83
Crooked Fork	Existing Debris	>24" DBH	18	15	83	2	11	17	94	99
White Sand	Existing Debris	>24" DBH	3	2	67	1	33	3	100	53
TOTAL	Existing Debris	>24" DBH	21	17	81	3	14	20	95	93

Table 7. Comparison of organic debris providing habitat one year after installation by habitat type, in Crooked Fork and White Sand Creek, 1984.

Stream	Type Of Structure	Habitat Type	Number of Structures	Number Actively Scouring	Percent Of Total	Number Suspended	Percent Of Total	Total Providing Habitat	Percent Of Total	Ft2 of Pool Habitat Structure
Crooked Fork	Live Tree	Pool	30	16	53	7	23	23	76	97
White Sand	Live Tree	Pool	31	13	42	10	32	23	74	55
TOTAL	Live Tree	Pool	61	29	48	17	28	46	75	75
Crooked Fork	Live Tree	Riffle	85	19	22	37	44	56	66	24
White Sand	Live Tree	Riffle	21	7	33	10	48	17	81	40
TOTAL	Live Tree	Riffle	106	26	25	47	44	73	67	25
Crooked Fork	Live Tree	Run	5	2	40	1	20	3	60	77
White Sand	Live Tree	Run	26	7	27	11	42	18	69	73
TOTAL	Live Tree	Run	31	9	29	12	39	21	68	74
Crooked Fork	Existing Debris	Pool	10	9	90	1	10	10	100	103
White Sand	Existing Debris	Pool	5	3	60	2	40	5	100	136
TOTAL	Existing Debris	Pool	15	12	80	3	20	15	100	114
Crooked Fork	Existing Debris	Riffle	34	15	47	10	29	25	74	59
White Sand	Existing Debris	Riffle	7	4	57	1	14	5	71	176
TOTAL	Existing Debris	Riffle	41	19	46	11	27	30	73	79
Crooked Fork	Existing Debris	Run	4	4	100	—	—	4	100	45
White Sand	Existing Debris	Run	3	2	67	1	33	3	100	131
TOTAL	Existing Debris	Run	7	6	86	1	14	7	100	82

Structures existing 3:' placed in pool habitat types consistantly created more pool habitat with run habitat second (Table 7). Variability was again high but live trees placed in riffles showed the greatest difference. Live structures placed in riffles produced almost three times less pool habitat than runs or pools but it Is important to note that these differences were not as great when comparing existing debris by habitat type, Indicating that riffles can produce good habitat with time.

Structures were identified as to their location in the stream meander to determine if location had an effect on viability or effectiveness. A total of 213 of 261 structures were placed in straight sections of the stream while 16 were placed in the outside curve of the meander and 27 were placed on the inside of the meander (Table 8).

Existing debris structures in straight sections had the highest effectiveness rate of 31 5 and the majority of these were scouring. Live trees placed in the inside of meanders had the lowest effectiveness rate consisting of 57% of the total and only 13': were actually scouring. Existing debris structures also 'had a low effectiveness rate (50%) for placement on inside of menaders but the sample size is very small (n=4) (Table 8).

When comparing the amount of pool habitat created by meander type, inside meanders had the least success. Existing debris structures produced no habitat in inside meanders with a sample size of one, but the low sample size of one also indicates that it was difficult to find good existing debris in inside meanders. The area of pool created by live structure in inside meanders were 1.9 and 1.7 times less, respectively, when compared to outside meanders and straight sections. The low water depths and lack of higher velocities evidently created poor conditions for creating habitat in inside meanders.

IL was attempted to concentrate structures in side channels during 1983 but these areas were severely limiting on both streams. White Sand Creek had no areas suitable for structures In side channels except for one existing debris structure (Table 9). It was theorized that structures in side channels would have a better chance of survival due to lower flows and velocities.

Side channels containing both live trees and existing debris had higher rates of effectiveness (88% and 100% respectively) than structures in the mainstens (70% for live trees and 803 for existing debris) (Table 9). Numbers of live trees that were actively scouring were low, 33% and 29% for mainstem trees and side channels respectively.

Structures in side channels consistently created more pool habitat with the most significant difference between existing debris (293 ft^2/structure for side channels vs 77ft^2/structure for mainsten), although the sample size for side channels with existing debris is too low to make any concrete conclusions (Table 9).

Table 8. Comparison of organic debris providing habitat. one year after installation by location in stream meander, in Crooked Fork and White Sand Creeks, 1984.

Stream	Type Of Structure	Location	Number Structures	Number Actively Scouring	Percent Of Total	Number Suspended	Percent Of Total	Total Providing Habitat	Percent Of Total	Ft^2 Pool Habitat P Structure
Crooked Fork	Live Tree	Inside Meander	12	1	8	5	42	6	50	6
White Sand	Live Tree	Inside Meander	11	2	18	5	45	7	64	55
TOTAL	Live Tree	Inside Meander	23	3	13	10	43	13	57	20
Crooked Fork	Live Tree	Outside Meander	7	1	14	4	57	5	71	55
White Sand	Live Tree	Outside Meander	4	2	50	2	50	4	100	58
TOTAL	Live Tree	Outside Meander	11	3	27	6	55	9	82	56
Crooked Fork	Live Tree	Straight	103	35	34	35	34	70	68	47
White Sand	Live Tree	Straight	61	25	39	18	30	43	70	63
TOTAL	Live Tree	Straight	164	60	37	53	32	113	69	53
Crooked Fork	Existing Debris	Inside Meander	—	—	—	—	—	—	—	—
White Sand	Existing Debris	Inside Meander	1	1	100	—	—	1	100	0
TOTAL	Existing Debris	Inside Meander	4	2	50	—	—	2	50	0
Crooked Fork	Existing Debris	Outside Meander	3	1	33	—	—	1	33	33
White Sand	Existing Debris	Outside Meander	5	4	80	—	—	4	80	11
TOTAL	Existing Debris	Outside Meander	5	4	80	—	—	4	80	10
Crooked Fork	Existing Debris	Straight	43	28	65	11	26	39	91	74
White Sand	Existing Debris	Straight	11	5	45	5	45	10	90	68
TOTAL	Existing Debris	Straight	54	33	61	16	30	49	91	72

Table 9. Comparison of organic debris providing habitat one year after installation by location in stream, by reach, in Crooked Fork and White Sand Creek, 1984.

Stream	Type Of Structure	Location	Number Structures in	No. Actively Scoring	Percent Of Total	Number Suspended	Percent Of Total	All	Percent Of Total
Crooked Fork	Live Tree	Mainstem	103	32	32	35	34	67	65
White Sand	Live Tree	Mainstem	78	28	36	31	40	59	76
TOTAL			181	60	33	66	36	126	70
Crooked Fork	Live Tree	Side Channel	17	5	29	10	59	15	88
White Sand	Live Tree	Side Channel	—	—	—	—	—	—	—
TOTAL			17	5	29	10	59	15	88
Crooked Fork	Existing Debris	Mainstem	46	26	57	11	24	36	80
White Sand	Existing Debris	Mainstem	14	8	57	4	14	12	71
TOTAL			60	34	57	15	25	48	80
Crooked Fork	Existing Debris	Side Channel	2	2	100	—	—	2	100
White Sand	Existing Debris	Side Channel	1	1	100	—	—	—	—
TOTAL			3	3	100	—	—	2	100

When trees where observed that had been pushed on the stream bank it was attempted to pull them back into the stream. This proved to be virtually impossible. A western larch tree with a 24" d.b.h. and 100 ft long can weigh up to 12,000 pounds and this doesn't account for the additional weight of water absorbtion from being in the water all spring long. This conpounded with the fact that most sites had boulders further restricting the movement of the log, made it impossible to move the logs with simple winches and come-alongs. The remote location prevented larger equipment from being used.

The only maintenance possible was to add trees to existing structures when it was felt that the addition would enhance the site. Initial observations on the effectiveness of structures led to design changes in the additional structures installed.

In many cases trees that were felled in 1983 that met the criteria of greater than 24" d.b.h. were felled too far on the bank leaving only the small tops in the streams with little chance of providing much habitat (figs. 24 5 25). Therefore trees within 20 ft of the bank.; were felled to add as much debris as possible in the stream. In 1983, trees were limbed and resultant slash way piled beyond this high water mark to prevent the small debris from creating jams. Observations of naturally fallen trees indicated that this would not be a problem and it was felt that leaving the branches on would further diversify the habitat and would help stabilize the structure, therefore no structures were limbed.

The double wrap of 1/4" cable seemed adequate since incidents of cable breakage were actually low and tree tops generally broke off instead.

The angle at which the tree was felled did not seem to matter much since water flows and ice had the greatest effect on where the structure finally rested. Tree size seemed to be an important factor although final analysis (Table 5) did not show any significance between tree size.

It was apparent that for the structure to remain effective for any period of time they had co be constructed 30 they would remain in the mainstem of she stream even through ice flows. Structures that were observed working as intended were usually groups of trees working together, resting against each other as the water and ice flowed past them or' logs that were braced on the bank by standing trees that wouldn't allow them to move or were against boulders in the stream acting as stabilizing points (figs. 26-32).

Existing debris that was observed providing excellent habitat and relatively stable usually was a result of an old jan or' was a collection of several pieces of organic debris interlocking and making the structure itself stable.

Figure 24. Tree felled in Crooked Fork Creek Side Channel, 3/4 Reach, Site #9, 1983.

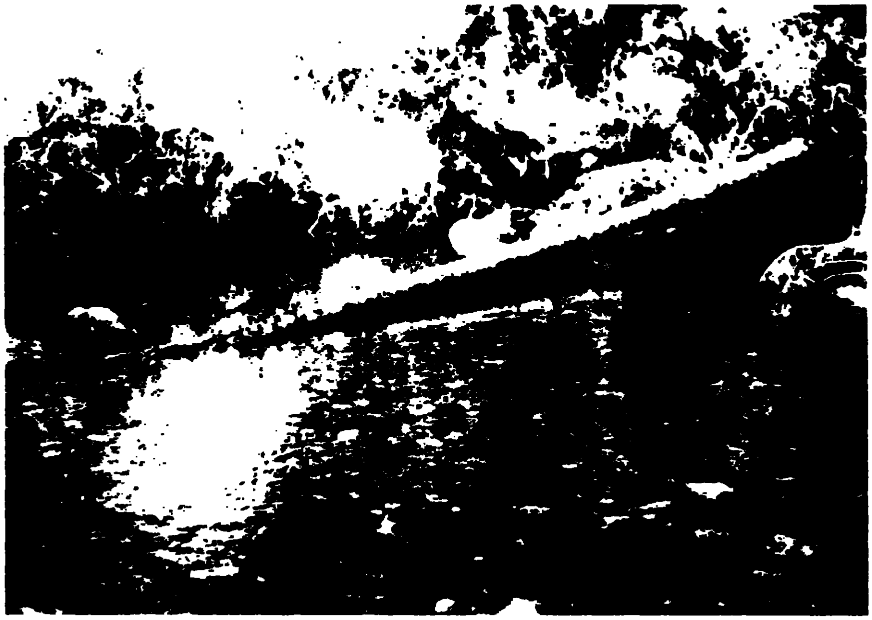


Figure 25. Tree felled in Crooked Fork Creek Side Channel, 3/4 Reach, Site #9, one year after installation, 1984.

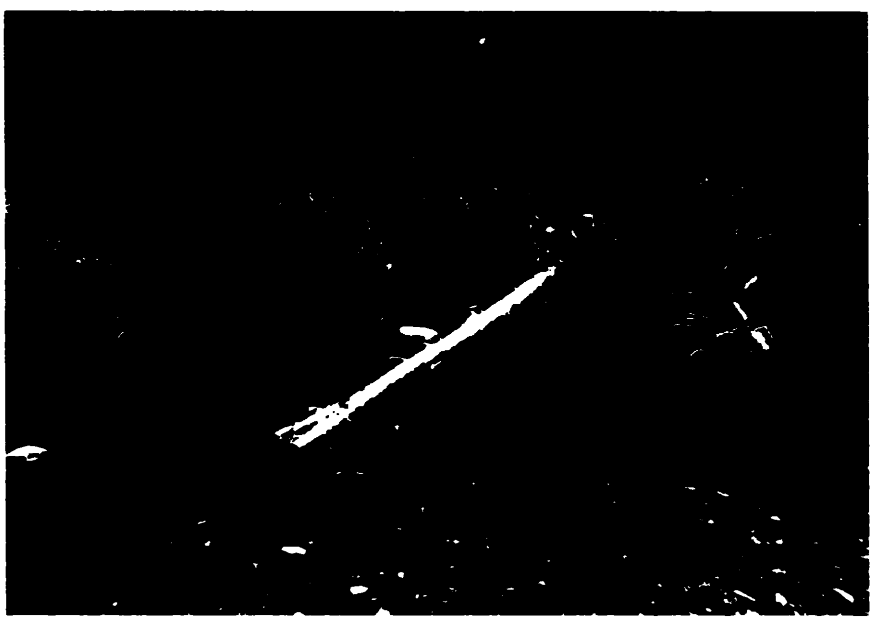


Figure 36 . Live trees felled in Crooked Fork Creek, Ford Reach, Site #8, 1983.

Figure 27 . Live trees felled in Crooked Fork Creek, Ford Reach Site #8, one year after installation, 1984.

Figure 28 . Large tree felled in White Sand Creek, Colt Creek Reach one year after installation, 1984.

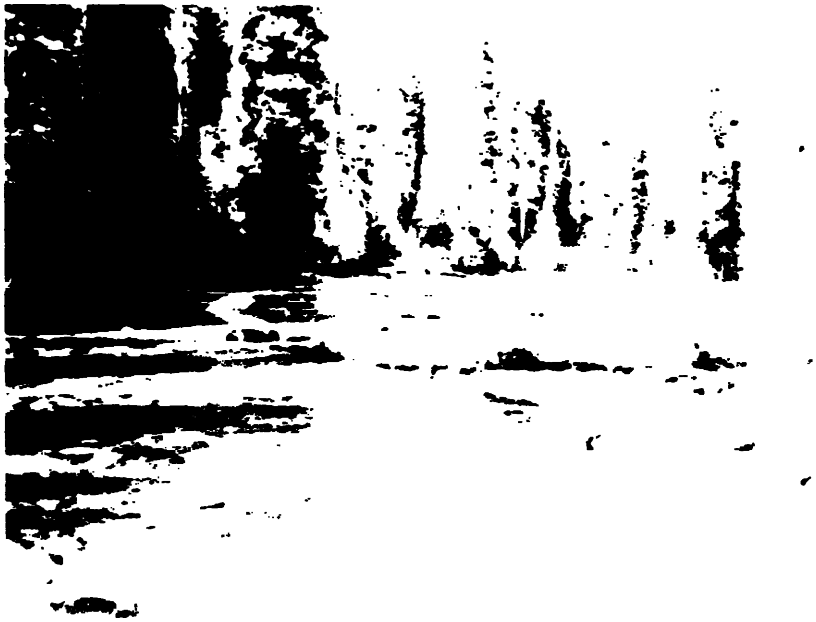
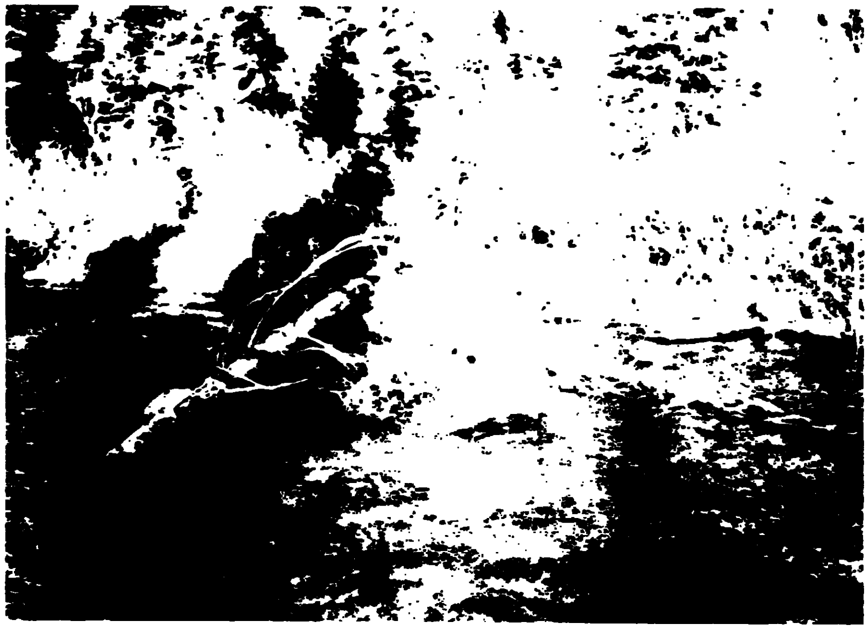


Figure 29 . White Sand Creek, Beaver Creek Reach shoving trees felled at Sites 18 and #9, one year after installation, 1984.

Figure 30. White Sand Creek, Corner Reach showing several structures still effective one year after installation, 1984.

Figure 31. White Sand Creek, Corner Reach showing three structures still effective one year, after installation, 1984.

Figure 32. Live tree felled in Crooked Fork Creek, Ford Reach, Site #l one year after installation, 1984.



Several other types of structures were developed and installed to meet these criteria (see methods). The types and numbers of different structures are displayed in Table 10. These structures are experimental therefore total numbers of each were limited. Another factor that prevented additional trees from being felled was that only the best trees and locations were selected. Although the riparian area along these streams is abundant with large trees, the lean of the trees, distance from the bank, and bank heights greatly limit the numbers of trees that are appropriate for falling.

A total of 19 trees were installed that were either added to existing structures or were cabled to the stumps using criteria mentioned before. Eight jetty structures were installed. These structures are designed with a downstream brace (figs. 3-5) which will give support and maintain itself in position in water. It is also designed to collect other organic debris to further enhance the sight.

Two downstream "V"s were installed in side channels and have the same characteristics of jetties but are probably stronger, but can only be installed in narrow channels.

Four trees were felled and rebarred. The rebar is designed to hold the structure in place. The Pionjar rock drill with a bar driving bit worked well in driving the 3/4" rebar up to 7 ft into the substrate.

<u>Summary and Conclusions</u>

Preproject field surveys in 1983 indicated that natural deposits of organic debris were enhancing the habitat and fish populations by creating diversity and hiding cover for emergent fry, scouring pools for the larger juveniles enhancing pool quality by adding cover, and by retaining gravels suitable for spawning. Several researchers have documented the importance of organic debris in streams and its value to fish populations (Meehan, et. al. 1977, Triska, et. al. 1982, Sedel and Luchessa, 1981).

The structures installed and secured were designed to emulate these conditions and to prolong their existence in the system.

Ice jams will continue to have a significant effect on structures placed in streams of this size but data did show that surprisingly few structures actually had broken cables. The fact that 74% of all structures installed were still providing some kind of habitat after these conditions is astounding.

Although a number of structures were above the water surface during low flows, data indicated that besides providing just cover, they also had pool habitat associated with them. Further investigation showed that existing debris above water produced almost 73% of the habitat provided by existing debris actively scouring. Therefore structures that are installed with live trees out of the water should continue to develop better habitat.

Table 10. Additional structures installed in Crooked Fork and White Sand Creek by type of structure, 1984.

Stream	No. Trees Felled	No. Rebar	No. Cabled Only	No. Jetty	No. Downstream "V"
Crooked Fork	19	3	9	1	2
White Sand	25	1	10	7	0
TOTAL	44	4	19	8	2

Data indicated several factors to be considered when installing future structures:

Large tree size is important for maximizing the amount of habitat produced.

Structures placed in pool and run habitat are more effective in producing habitat and in longevity.

Avoid inside meanders because of lack of effectiveness and amount of habitat produced.

The comparison of side channels vs mainstem don't show any clear evidence in effectiveness and of no definite conclusion can be made for which type of reach produces the most habitat.

Limbs should be left on the trees. The protusions of the limbs will help diversify the habitat and will help stabilize the structure.

Observations of existing debris indicated that root wads of trees were Important in the quality and effectiveness of the structures. The roots were extremely valuable in diversifying the habitat but also provided an anchor for stabilizing the structure. Further observations indicated that the more trees intermingled in the structures the better the habitat.

Methods that could better duplicate these conditions would be more effective. Some work has been tried blasting the root wad into the stream with limited success but efforts should continue in this area. Areas with better access could utilize heavy equipment to push or pull the trees In.

Maintenance of the structures was very difficult. in some cases trees could be recabled but actual moving an ineffective structure was virtually impossible due to the type of equipment available for use in remote areas. Generally adding trees to structures is limited due to the availability of trees in the area with proper lean or location.

The different design types installed in 1984 should be monitored to see if they can produce better habitat over a longer period of time.

Continued efforts should be made in monitoring the 1983 structures. A; though performance of these structures do not equal those of log weirs, there low unit cost and the fact that they can be instailed in remote areas with very little equipment makes them very appealing (figs. 33-36).

The bottom line is their effect on fish populations. It is extremely important than an evaluation critically looks at the benefits of these structures. Efforts have begun through Idaho Department of Fish and Game to evaluate this portion of the project. This project should be funded on a long term basis not only because of the slow fish response, due to anadromous fish cycles and low seeding rates, but also due to the fact that data indicates that these structures may continue to develop habitat with time.

Figure 33. Aerial view of two structures on Crooked Fork Creek, Reach above Highway 12 Bridge, one year after installation, 1984. Note upper structure collecting additional organic debris.

Figure 34. Aerial view of three structures on Crooked Fork Creek, Reach above Highway 12 Bridge, one year after installation, 1984.

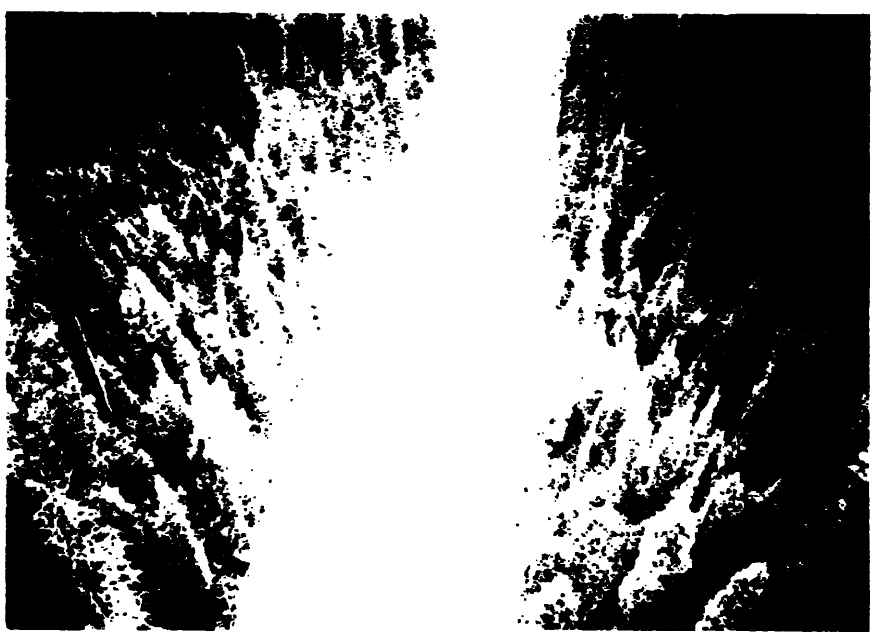


Figure 35 . Aerial view of two structures on Crooked Fork Creek, Reach above Highway 12 Bridge, one year after installation, 1984.

Figure 36 . Aerial view of me structure on Crooked Fork Creek, Reach above Highway 12 Bridge, one year after installation, 1984.

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APPENDICES

Appendix A: Summary of Expenditures

Appendix B: Supplemental Tables

APPENDIX A

SUMMARY OF EXPENDITURES

SALARIES	6325
TRAVEL	-----
NON-EXPENDABLE EQUIPMENT AND MATERIAL	380
EXPENDABLE EQUIPMENT AND MATERIAL OVERHEAD	-----
OPERATION AND MAINTENANCE	2230
OVERHEAD	1065
TOTAL	10,000

Appendix B

Table 1 . Comparison of organic debris by reach with broken cables as rendered ineffective one year after installation in White Sands Creek, 1984.

White Sand

Live Trees

Reach	Number Trees Felled	Number with Broken Cable	Percent	Numbered Washed up on the Bank	Percent
T.B.	12	0	0	2	16
C.R.	5	0	0	2	40
C.C.R.	21	0	0	4	19
B.C.R.	11	0	0	1	9
C.C.C.R.	29	1	3	8	27
TOTAL	78	1	1	17	21

Existing Debris

Reach	Number of Structures	Number with Broken Cable	Percent	Number Washed up on the Bank	Percent
T.B.	6	0	0	0	0
C.R	0	0	0	0	0
C.C.R.	2	0	0	0	0
B.C.R.	0	0	0	0	0
C.C.C.R.	7	1	14	1	14
TOTAL	15	1	6	1	6

Table 2 . Range of angles of structure in White Sand and Crooked Fork Creek, 1984.

Crooked Fork

Live Trees			Existing Debris		
Reach	Range of Angles	Mean	Reach	Range of Angles	Mean
T.B.	25° to 60°	38°	T.B.		
D.R.	25° to 70°	43°	D.R.	20° to 48°	22°
R.A.D.	60° to 70°	67°	R.A.D.	10° to 70°	38°
3/4 S.	20° to 90°	47°	3/4 S.	15° to 30°	21°
HWY 12B	30° to 90°	54°	HWY 12B		
HWY 12A	20° to 60°	42°	HWY 12A	10° to 90°	40°
Ford	20° to 70°	40°	Ford	20° to 42°	25°
TOTAL	20° to 90°		TOTAL	10° to 90°	

White Sand

Live Trees			Existing Debris		
Reach	Range of Angles	Ave.	Reach	Range of Angles	Ave.
T.B.	20° to 50°	24°	T.B.	10° to 60°	39°
C.R.	20° to 55°	42°	C.R.		
C.C.R.	25° to 90°	50°	C.C.R.	35° to 60°	47°
B.C.R.	40° to 100°	68°	B.C.R.		
C.C.C.R.	20° to 90°	53°	C.C.C.R.	35° to 90°	75°
TOTAL	20° to 100°		TOTAL	10° to 90°	

Table 3 . Comparison of organic debris by reach with broken cables or rendered ineffective one year after installation in Crooked Fork Creek, 1984.

Crooked Fork

Live Trees

Reach	Number Trees Felled	Number with Broken Cable	Percent	Number Washed up on the Bank	Percent
T.B.	7	0	0	2	28
D.R.	17	3	18	3	18
R.A.D.	3	0	0	3	100
3/4 S.	13	0	0	2	15
HWY 12B	24	3	12	1	4
HWY 12A	33	5	15	3	9
Ford	23	0	0	3	13
TOTAL	120	11	9	17	14

Existing Debris

Reach	No. of Structures	Number with Broken Cable	Percent	Number Washed up on the Bank	Percent
T.B.	0	0	0	0	0
D.R.	8	0	0	0	0
R.A.D.	7	1	14	0	0
3/4 S.	3	0	0	0	0
HWY 12B	0	0	0	0	0
HWY 12A	24	3	12	1	4
Ford	6	0	0	0	0
TOTAL	48	4	8	1	2

Table 4. Comparison of organic debris providing habitat one year after installation by location in stream, by reach in Crooked Fork Creek, 1984.

Live Trees

Reach	No. of Trees Located in Mainstem	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	7	2	28	2	28	4	57
D.R.	17	9	53	3	18	12	71
R.A.D.	3	0	0	0	0	0	0
3/4 S.	5	2	40	1	20	3	60
HWY 12B	15	0	0	7	46	7	46
HWY 12A	33	11	33	13	39	24	72
Ford	23	8	35	9	39	17	24
TOTAL	103	32	32	35	34	67	65

Reach	No. of Trees Located in Side Channels	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	8	3	37	3	37	6	75
HWY 12B	9	2	22	7	78	9	100
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	17	5	29	10	59	15	88

Table 4 (cont.).

Existing Debris

Reach	No. of Trees Located in Mainstem	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	8	8	100	0	0	8	100
R.A.D.	7	6	86	1	14	7	100
3/4 S.	1	1	100	0	0	1	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	24	8	33	7	21	15	63
Ford	6	3	50	3	50	6	100
TOTAL	46	26	57	11	24	37	80

Reach	No. of Trees Located in Side Channels	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	2	2	100	0	0	2	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	2	2	100	0	0	2	100

Table 5 . Comparison of organic debris providing habitat one year after installation, by location in stream, by reach in White Sand Creek, 1984.

Live Trees

Reach	No. of Trees Located in Mainstem	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	12	5	42	5	42	10	84
C.R.	5	1	20	2	40	3	60
C.C.R.	21	7	33	10	48	17	81
B.C.R.	11	4	36	6	54	10	90
C.C.C.R.	29	11	38	8	27	19	62
TOTAL	78	28	36	31	40	59	76

Reach	No. of Trees Located in Side Channels	No. Actively Scouring	Percent	Number Suspended at Low Flows		Percent	All
Percent							
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	0	0	0	0	[illegible]	[illegible]	0

Table 5 (cont.).

Existing Debris

Reach	No. of Trees Located in Main Channel	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	6	4	67	2	33	6	100
C.R.	0	0	0	0	0	0	0
C.C.R.	2	2	100	0	0	2	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	6	2	33	2	33	4	66
TOTAL	14	8	57	4	14	12	71

Reach	No. of Trees Located in Side Channels	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	1	1	100	0	0	1	100
TOTAL	1	1	100	0	0	1	100

Table 6 . Comparison of organic debris providing habitat one year after installation by loction in stream meander, by reach in Crooked Fork Creek, 1984.

Live Trees

Reach	No. of Trees Located Inside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	2	0	0	0	0	0	0
3/4 S.	0	0	0	0	0	0	0
HWY 12B	3	0	0	2	66	2	66
HWY 12A	7	1	14	3	43	4	57
Ford	0	0	0	0	0	0	0
TOTAL	12	1	8	5	42	6	50

Reach	No. of Trees Located Outside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	3	1	33	1	33	2	66
HWY 12B	4	0	0	3	75	3	75
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	17	1	14	4	57	5	71

Reach	No. of Trees Located Straight	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	7	2	28	0	0	2	28
D.R.	17	9	53	3	18	12	71
R.A.D.	1	0	0	0	0	0	0
3/4 S.	10	4	40	3	30	7	70
HWY 12B	17	2	12	10	59	12	71
HWY 12A	27	10	37	10	37	20	74
Ford	24	8	33	9	38	17	71
TOTAL	103	35	34	35	34	70	68

Table 6 (cont.).

Existing Debris

Reach	No. of Trees Located Inside Meander	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	0	0	0	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	3	1	33	0	0	1	33
Ford	0	0	0	0	0	0	0
TOTAL	3	1	33	0	0	1	33

Reach	No. of Trees Located Outside Meander	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	0	0	0	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0

Reach	No. of Trees Located Outside Meander	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	8	8	100	0	0	8	100
R.A.D.	7	6	86	1	14	7	100
3/4 S.	3	3	100	0	0	3	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	19	8	42	7	37	15	79
Ford	6	3	50	3	50	6	100
TOTAL	43	28	65	11	26	39	91

Table 7 . Comparison of organic debris providing habitat one year after installation by location in stream meander, by reach in White Sand Creek, 1984.

Live Trees

Reach	No. of Trees Located Inside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	4	1	25	1	25	2	50
C.C.R.	3	0	0	2	67	2	67
B.C.R.	3	0	0	2	67	2	67
C.C.C.R.	1	1	100	0	0	1	100
TOTAL	11	2	18	5	45	7	64

Reach	No. of Trees Located Outside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	4	2	50	2	50	4	100
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	4	2	50	2	50	4	100

Reach	No. of Trees Located Straight	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	10	5	50	0	0	5	50
C.R.	1	1	25	0	0	1	25
C.C.R.	18	7	39	8	44	15	83
B.C.R.	4	2	50	2	50	4	100
C.C.C.R.	28	10	36	8	28	18	64
TOTAL	51	25	39	18	30	43	70

Table 7 (cont.).

Existing Debris

Reach	No. of Trees Located Inside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	1	1	100	0	0	1	100
TOTAL	1	1	100	0	0	1	100

Reach	No. of Trees Located Outside Meander	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	2	2	100	0	0	2	100
C.R.	0	0	0	0	0	0	0
C.C.R.	2	2	100	0	0	2	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	1	0	0	0	0	1	0
TOTAL	5	4	80	0	0	5	80

Reach	No. of Trees Located Straight	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	4	2	50	2	50	4	100
C.R.	1	0	0	1	100	1	100
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	6	3	50	2	33	5	83
TOTAL	11	5	45	5	45	10	90

Table 8. Comparison of organic debris providing habitat one year after installation by habitat type in Crooked Fork Creek, 1984.

Live Trees

Reach	No. of Trees in Pool	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	10	8	80	1	10	9	90
R.A.D.	2	0	0	0	0	0	0
3/4 S.	9	3	33	4	44	7	77
HWY 12B	2	1	50	1	50	2	100
HWY 12A	2	0	0	1	50	1	50
Ford	5	4	80	0	0	4	80
TOTAL	30	16	53	7	23	23	76

Reach	No. of Trees Located Riffle	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	6	2	33	1	17	3	50
D.R.	7	1	14	2	29	3	43
R.A.D.	0	0	0	0	0	0	0
3/4 S.	3	1	33	0	0	1	33
HWY 12B	21	1	5	13	62	14	67
HWY 12A	30	10	33	12	40	22	73
Ford	18	4	22	9	50	13	72
TOTAL	85	19	22	37	44	56	66

Reach	No. of Trees Located Run	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	1	0	0	1	100	1	100
D.R.	0	0	0	0	0	0	0
R.A.D.	1	0	0	0	0	0	0
3/4 S.	1	1	100	0	0	1	100
HWY 12B	1	0	0	0	0	0	0
HWY 12A	1	1	100	0	0	1	100
Ford	0	0	0	0	0	0	0
TOTAL	5	2	40	1	20	3	60

Table 8. (Cont.)

Existing Debris

Reach	No. of Trees Located Pool	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	5	5	100	0	0	5	100
R.A.D.	0	0	0	0	0	0	0
3/4 S.	2	2	100	0	0	2	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	2	1	50	1	50	2	100
Ford	1	1	100	0	0	1	100
TOTAL	10	9	90	1	10	10	100

Reach	No. of Trees Located Riffle	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	3	3	100	0	0	3	100
R.A.D.	3	2	67	1	33	3	100
3/4 S.	1	1	100	0	0	1	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	22	7	32	6	27	13	59
Ford	5	2	40	3	60	5	100
TOTAL	34	15	47	10	29	25	74

Reach	No. of Trees Located Run	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	4	4	100	0	0	4	100
3/4 S.	0	0	0	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	4	4	100	0	0	4	100

Table 9 . Comparison of organic debris providing habitat, one year after installation by habitat type, in White Sand Creek, 1984.

Live Trees

Reach	No. of Trees in Pools	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	4	2	50	2	50	4	100
B.C.R.	3	2	67	1	33	3	100
C.C.C.R.	24	9	38	7	29	16	67
TOTAL	31	13	42	10	32	23	74

Reach	No. of Trees in Riffle	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	7	4	57	3	43	7	100
C.R.	0	0	0	0	0	0	0
C.C.R.	1	0	0	1	100	1	100
B.C.R.	8	2	25	5	62	7	87
C.C.C.R.	5	1	20	1	20	2	40
TOTAL	21	7	33	10	48	17	81

Reach	No. of Trees in Run	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	5	1	20	2	40	3	60
C.R.	5	1	20	2	40	3	60
C.C.R.	16	5	31	7	44	12	75
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	26	7	27	11	42	18	69

Table 9. (Cont.)

Existing Debris

Reach	No. of Trees in Pools	No. Actively Scouring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	5	3	60	2	40	5	100
TOTAL	5	3	60	2	40	5	100

Reach	No. of Trees in Riffle	No. Actively Scoring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	3	2	67	1	33	3	100
C.R.	0	0	0	0	0	0	0
C.C.R.	2	2	100	0	0	2	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	2	0	0	0	0	0	0
TOTAL	7	4	57	1	14	5	71

Reach	No. of Trees in Run	No. Actively Scoring	Percent	Number Suspended at Low Flows	Percent	All	Percent
T.B.	3	2	67	1	33	3	100
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	3	2	67	1	33	3	100

Table 10. Comparison of organic debris providing habitat one year after installation by tree size, by reach in Crooked Fork and White Sand Creek, 1984.

Reach	No. of Trees Greater Than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Less Than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Greater than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Less Than 24" DBH	Number Actively Scouring	Number Suspended
T.B.	2	0	2	5	2	0	0	0	0	0	0	0
D.R.	9	5	2	8	4	1	6	6	0	2	2	0
R.A.D.	3	0	0	0	0	0	6	5	1	1	1	0
3/4 S.	4	2	1	9	3	3	0	0	0	3	3	0
HWY 12B	10	0	9	14	2	5	0	0	0	0	0	0
HWY 12A	8	3	2	25	8	11	5	3	1	19	5	6
Ford	3	0	2	20	8	7	1	1	0	5	2	3
TOTAL	39	10	18	81	27	27	18	15	2	30	13	9

White Sand Creek

Reach	No. of Trees Greater Than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Less Than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Greater than 24" DBH	Number Actively Scouring	Number Suspended	No. of Trees Less Than 24" DBH	Number Actively Scouring	Number Suspended
T.B.	3	2	1	9	3	4	2	1	1	4	3	1
C.R.	2	1	0	3	0	2	0	0	0	0	0	0
C.C.R.	10	1	5	11	6	5	0	0	0	2	2	0
B.C.R.	4	1	2	7	3	4	0	0	0	0	0	0
C.C.C.R.	15	7	3	14	4	5	1	1	0	6	2	2
TOTAL	34	12	11	44	16	20	3	2	1	12	7	3

Combined Totals

GRAND TOTAL	73	22	29	125	43	47	21	17	3	42	20	12

Table 11. Comparison of organic debris providing habitat one year after installation by angle in stream, by reach in Crooked Fork, 1984.

Live Trees

Reach	No. of Trees <20°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	0	0	0	0	0	0	0
R.A.D.	0	0	0	0	0	0	0
3/4 S.	1	1	100	0	0	1	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	0	0	0	0	0	0	0
Ford	2	0	0	1	50	1	50
TOTAL	3	1	33	1	33	2	66

Reach	Number of Trees 20°-30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	2	1	50	0	0	1	50
D.R.	2	2	100	0	0	2	100
R.A.D.	0	0	0	0	0	0	0
3/4 S.	0	0	0	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	0	0	0	0	0	0	0
Ford	0	0	0	0	0	0	0
TOTAL	4	3	75	0	0	3	75

Reach	No. of Trees >30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	5	1	20	2	40	3	60
D.R.	15	7	47	3	20	10	67
R.A.D.	3	0	0	0	0	0	0
3/4 S.	12	4	33	4	33	8	66
HWY 12B	24	2	8	14	58	16	66
HWY 12A	33	11	34	13	39	24	73
Ford	21	8	38	8	38	16	76
TOTAL	114	33	29	44	38	77	67

Table 11. (Cont.)

Existing Debris

Reach	No. of Trees <20°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	5	5	100	0	0	5	100
R.A.D.	5	5	100	0	0	5	100
3/4 S.	2	2	100	0	0	2	100
HWY 12B	0	0	0	0	0	0	0
HWY 12A	15	4	27	6	40	10	67
Ford	3	1	33	2	67	3	100
TOTAL	30	17	56	8	27	25	83

Reach	Number of Trees 20°-30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	1	1	100	0	0	1	100
R.A.D.	1	1	100	0	0	1	100
3/4 S.	0	0	0	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	1	1	100	0	0	1	100
Ford	2	1	50	1	50	2	100
TOTAL	5	4	80	1	10	5	100

Reach	No. of Trees >30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
D.R.	2	2	100	0	0	2	100
R.A.D.	1	0	0	1	100	1	100
3/4 S.	1	1	100	0	0	0	0
HWY 12B	0	0	0	0	0	0	0
HWY 12A	8	3	37	1	13	4	50
Ford	1	1	100	0	0	1	100
TOTAL	13	7	54	2	15	9	69

Table 12. Comparison of organic debris providing habitat one year after installation by angle in stream by reach in White Sand Creek, 1984.

White Sand
Live Trees

Reach	No. of Trees <20°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	2	0	0	2	100	2	100
C.R.	1	0	0	1	100	1	100
C.C.R.	2	1	50	1	50	2	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	1	0	0	0	0	0	0
TOTAL	6	1	17	4	66	5	83

Reach	Number of Trees 20°-30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	1	0	0	1	100	1	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	1	0	0	1	100	1	100

Reach	No of Trees >30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	10	5	50	3	30	8	80
C.R.	4	1	25	1	25	2	50
C.C.R.	18	6	33	8	44	14	77
B.C.R.	11	4	36	6	54	10	90
C.C.C.R.	27	11	41	8	29	19	70
TOTAL	70	27	38	26	37	53	75

Table 12(cont.).

White Sand
Existing Debris

Reach	No. of Trees <20°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	4	3	75	1	25	4	100
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	4	3	75	1	25	4	100

Reach	Number of Trees 20°-30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	0	0	0	0	0	0	0
C.R.	0	0	0	0	0	0	0
C.C.R.	0	0	0	0	0	0	0
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0

Reach	No. of Trees >30°	No. Actively Scouring	Percent	Number Suspended	Percent	All	Percent
T.B.	2	1	50	1	50	2	100
C.R.	0	0	0	0	0	0	0
C.C.R.	2	2	100	0	0	2	100
B.C.R.	0	0	0	0	0	0	0
C.C.C.R.	7	3	43	2	28	5	71
TOTAL	11	6	54	3	27	9	81

Table 13 . Square feet of pool habitat created by type of structure, pool class and maximum pool depths, by reach in White Sand Creek, 1984.

White Sand
Live Trees

No. Sites	Reach	Square Foot of Pool 1	%	2	%	3	%	All	Pool	Range Of Depths	Mean
9	T.B.	0	0	667	50	675	50	1342	1.3'	0.6'	1.0'
5	C.R.	0	0	440	100	0	0	440	1.8'	1.8'	1.8'
15	C.C.R.	804	79	220	21	0	0	1024	2.0'	0.5'	0.9'
9	B.C.R.	186	35	341	65	0	0	527	2.2'	0.5'	1.2'
25	C.C.C.R.	825	44	408	22	626	34	1859	2.6'	0.5'	1.5'
63	TOTAL	1815	35	2076	40	1301	25	5192			

Existing Debris

No. Sites	Reach	Square Foot of Pool 1	%	2	%	3	%	All	Pool	Range Of Depths	Mean
6	T.B.	830	100	0	0	0	0	830	1.4'	0.4'	0.9'
0	C.R.	0	0	0	0	0	0	0	0.0'	0.0'	0.0'
2	C.C.R.	76	100	0	0	0	0	76	1.5'	1.4'	1.4'
0	B.C.R.	0	0	0	0	0	0	0	0.0'	0.0'	0.0'
6	C.C.C.R.	216	32	465	68	0	0	681	1.5'	1.3'	1.4'
14	TOTAL	1122	71	465	29	0	0	1587			

Table 14. Square foot of pool habitat created by type of structure, pool class and maximum pool depths, by reach in Crooked Fork Creek, 1984.

Crooked Fork
Live Trees

No. Sites	Reach	Square Foot of Pool 1	%	2	%	3	%	Total	Pool	Range Of Depths	Mean
5	T.B.	228	73	85	27	0	0	313	1.0'	0.7'	0.8'
13	D.R.	635	26	425	18	1340	56	2400	2.0'	0.6'	1.3'
6	R.A.D.	0	0	0	0	0	0	0	0.0'	0.0'	0.0'
11	3/4 S.	335	34	318	32	330	34	983	2.8'	0.3'	1.2'
18	HWY 12B	352	51	340	49	0	0	692	1.5'	0.4'	1.1'
24	HWY 12A	144	25	331	58	96	17	571	1.5'	0.4'	0.9'
16	Ford	46	9	459	91	0	0	505	2.5'	0.1'	1.0'
93	TOTAL	1740	32	1958	36	1766	32	5464			

Existing Debris

No. Sites	Reach	Square Foot of Pool 1	%	2	%	3	%	Total	Range Of Pool	Depths	Mean
0	T.B.	0	0	0	0	0	0	0	0.0'	0.0'	0.0'
5	D.R.	256	25	748	75	0	0	1004	1.9'	0.7'	1.7'
3	R.A.D.	0	0	945	100	0	0	945	3.6'	2.2'	2.8'
3	3/4 S.	42	21	111	55	50	24	203	2.0'	0.7'	1.4'
0	HWY 12B	0	0	0	0	0	0	0	0.0'	0.0'	0.0'
14	HWY 12A	77	11	358	52	256	37	691	1.5'	0.5'	1.1'
6	Ford	172	52	161	48	0	0	333	1.3'	0.5'	0.83'
31	TOTAL	547	17	2323	73	306	10	3176			

Table 15 . Additional structures installed in Crooked Fork and White Sand Creek by reach type of structure, 1984.

White Sand
Twin Bridges

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
6a	2	1	1	0	0
7	1	0	1	0	0
8	2	0	0	1	0
9	2	0	0	1	0
10	2	0	0	1	0
TOTAL	9	1	2	3	0

Cabin Creek

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
5	1	0	0	1	0
6	2	0	0	1	0
7	1	0	1	0	0
8	1	0	1	0	0
9	2	0	0	1	0
12	1	0	1	0	0
129	2	0	0	1	0
TOTAL	10	0	3	4	0

Beaver Creek

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
10	2	0	1	0	0
11	2	0	2	0	0
TOTAL	4	0	3	0	0

Table 15. (Cont.)

Colt Creek Cabin

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
14	1	0	1	0	0
17	1	0	1	0	0
TOTAL	2	0	2	0	0

Crooked Fork
Three Quarter

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
1a	2	0	2	0	0
2a	1	0	1	0	0
4	1	0	1	0	0
5	1	0	0	0	1
5a	1	0	1	0	0
6	1	0	1	0	0
6a	1	0	1	0	0
6b	2	0	1	0	0
6c	3	0	0	1	0
7a	1	1	0	0	0
8a	1	1	0	0	0
9a	1	0	1	0	0
10a	1	1	0	0	0
TOTAL	17	3	9	1	1

Reach Below Highway 12 Bridge

Site #	Number of Trees Felled	Total Rebar	Total Swing Free	Total Jetty	Total Downstream V
10a	2	0	0	0	1
TOTAL	2	0	0	0	1
GRAND TOTAL	44	4	19	8	2

CROOKED RIVER HABITAT IMPROVEMENT PROJECT

FINAL REPORT

PLANNING FOR THE RESTORATION OF MEANDERS ON A TRIAL BASIS

Prepared for

USDA Forest Service
Nez Perce National Forest
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CROOKED RIVER HABITAT IMPROVEMENT PROJECT

Planning for the restoration of Meanders on a Trial Basis

ABSTRACT

Long reaches of Crooked River, southwest of Elk City, Idaho, have been heavily impacted by gold dredging. Some reaches have been pushed to one side of the valley, straiqhtened and steepened. Vegetation, woody debris, shade, overhanging banks, and pools . . . components of diverse fish habitat, are in extremely short supply. High velocity riffles and large substrate are predominant.

Some preliminary habitat improvements have been completed by the Forest Service on several reaches of Crooked River. The project discussed in this report covers the hydrologic, geomorphic, river mechanics and bio-engineering aspects of considering the reconstruction of "pilot meanders" in a reach of Crooked River about three miles north of Orogrande, Idaho.

Consideration was given to several alternatives including: (1) installing habitat structures and a flood plain in existing reaches of Crooked River; (2) adding recessed backwater areas to the existing channel for rearing habitat; (3) building one or two pilot meanders just north of the emergency airstrip (the project reach); (4) cutting a more random channel through the dredge tailings in a less-constricted valley area upstream (south) of the airstrip; and (5) letting the stream continue to work towards its former natural state (do nothing).

The last alternative is not reasonable in light of the time required for natural restoration. Also, this project is part of a larger program for fish and wildlife improvement in the Columbia River basin.[1]

The major risk in meander restoration is the possible loss of water through the highly porous bed and banks. These would seal over time, but can be corrected with gravels, sands and fines during an initial, low-water diversion period. The design of the meanders is based on similar channels in the region and calls for lower than normal floodplains to encourage overbank flow, riparian vegetation and bank stabilization.

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1 Northwest Power Planning Council, 1984. Columbia River Basin Fish and Wilflife Program. Adopted Nov. 15, 1982; amended Oct. 10, 1984. Portland, Oregon, p. 56.

Acknowledgment

The project team members wish to express their thanks to Don Hair, project officer for the Elk City Ranger District on the Nez Perce National Forest. His timely communication, support services and thoughtful consideration of alternatives kept the project in perspective. The assistance of Wayne Paradis with our field work was sincerely appreciated.

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I. INTRODUCTION

Currently, as a result of sold dredqinq, the portion of Crooked River near the emergency airfield is flowinq on a steeper and straiqhter course than prior to dredging.

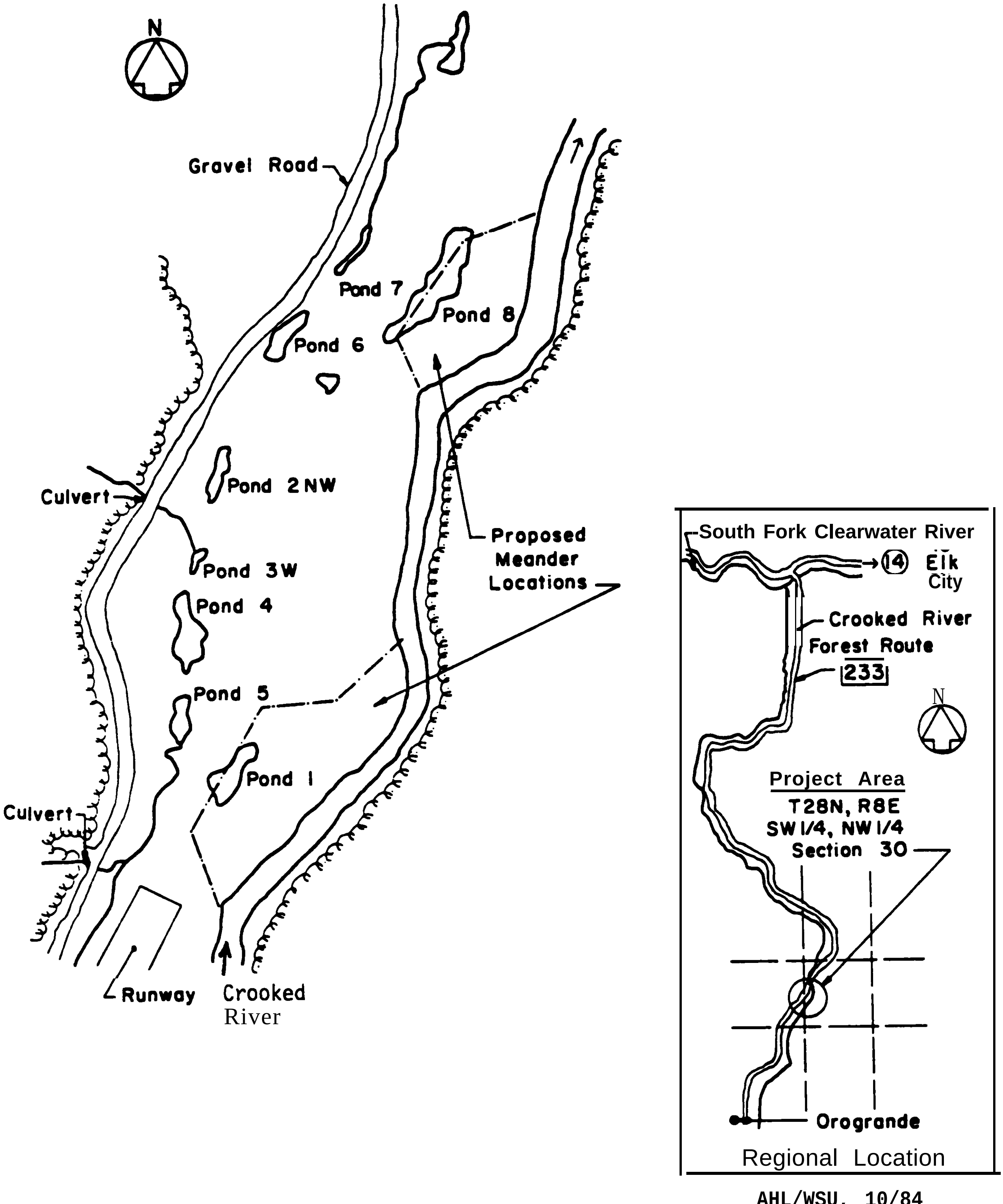
Therefore, this reach of Crooked River has less spawning and rearing habitat, velocities are higher, bed materials are larger and natural diversity in the channel (pools, riffles, woody debris and vegetative cover) is sorely lacking.

There are three major alternatives to consider in planning to restore fisheries habitat in Crooked River (see Figure 1 for site plan):

1. let the stream do the work and adjust over a longer period of time towards a more natural state;
2. add habitat enhancement features to the nearly straight existing channel along the east side of the valley; or
3. accelerate the process in (1) by constructing a meandering channel to the west of the existing river channel, through the dredge spoils, and utilize existing depressions and trees to enhance the habitat in the constructed meander(s).

Other minor alternatives are discussed in the next section.

This report has been prepared to document existing land and water information, Present the results of field investigations and office analysis, and provide guidance to Forest Service and Idaho Department of Fish and Game (IDFG) personnel in the selection of the appropriate alternative. This report does not discuss costs, but surveys and transects are presented so that cost estimates can be made by the Forest Service



Not to Scale

Figure 1. Crooked River Study Site Plan and Regional Location.

engineer assigned to the project. This information, plus the cost estimates for habitat improvement structures, will be used in developing costs of the alternatives.

The USFS has decided that two "pilot" meanders should be constructed, the WSU Project Team has field staked the meanders, and will orient the Forest Service Project Engineer to the site conditions.

Before discussing the alternative methods of improving spawning and rearing habitat at this "pilot study" site on Crooked River, there are certain geomorphic channel criteria which should be summarized in order to compare past, existing and future conditions.

1. Under natural conditions, the "pilot" channels of Crooked River would be about 2530% longer than they are now, and the reaches would probably be incised in a meadow[1].
2. The term "pilot" is being used because the habitat and productivity of the restored meanders are to be compared with the habitat and productivity of a "natural" (baseline) reach and a "straight" reach upstream beside the airfield where habitat improvement features (boulders, drop structures, trees and willows) have been installed.
3. The existing gradient of the valley is about 1.4% which is equal to the valley gradients in similar undisturbed meadows nearby, such as Ten-mile Creek just to the southwest.

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1 Details on design criteria and how they were developed are included in the chapter on Hydraulic Design of Meander Channels.

4. But, the natural channel slope in nearby streams is about 1.0%, whereas the present slope in Crooked River averages about 1.4%.
5. The length ratio of channel length (river) to valley length is 1.30 in natural channels and only about 1.05 in the study reach of Crooked River.
6. Changing the channel by restoring one or two meanders of 25% longer length than now exists will be primarily a gravel, cobble and soil moving project. Therefore, approximate cut and fill volumes have been estimated for both the upstream and downstream "pilot" meanders for preliminary comparison of alternatives.
7. Whether the existing channel were to be improved with habitat features (Alt. 2), or the meander(s) were to be restored (Alt. 3), similar habitat enhancement features would have to be installed in each channel.
8. The existing channel would require more constructed features than the pilot meanders, due to its steeper slope, its instability and tendency towards braiding, and its lack of natural pool structure.
9. The meander "pilot" channels can be constructed as close to natural conditions as desired, and the level of habitat features to be installed can be selected based on available funds *on* a year to year basis. Some of the "pilot" meander features for habitat enhancement are also hydraulic design features (glides, pools, riffles), and control structures such as log sills and large rocks.

10. Only two somewhat similar projects which involved the restoration of natural meanders in a dredged area were found in either the literature or through personal contacts.[2] Most habitat restoration in dredged spoils have involved the placement of habitat improvement structures in the existing channels, some channel reshaping and stabilization, and the use of shore plantings and/or woody debris.

II. DISCUSSION OF ALTERNATIVE METHODS FOR HABITAT IMPROVEMENT

Besides the three choices listed earlier, these alternatives exist:

1. Do nothing;
2. Improve the existing channel to a higher level than Alternative 2; and/or
3. Divide the river into two channels in order to double the potential habitat (preliminary consideration requested by USFS);

Another habitat improvement (for rearing) would be achieved by the connection of some existing ponds to the river by excavating a channel or culvert connection. This alternative No. (5) is discussed in this section, but cannot be compared directly with the other alternatives, except No. (l), do nothing. In a letter from District Ranger Bob Castaneda, dated September 12, 1984, the Forest Service chose not to consider improvements in the potential rearing ponds at this time. Other bases of comparison might be in terms of the relative amount of habitat improvement construction required by each alternative.

2 Boland, 1984: Brusven, et al., 1974; and Jackson and Van Haveren, 1984.

The preliminary assessment of these alternatives is presented on the next few pages using a method of Indices and a Decision Matrix. Referring to Table 1, the Alternatives are arranged across the top and Factors or Indices which will affect the effectiveness and project life of each Alternative are listed down the side.

The factors listed are not the only ones which can be considered. Space is left for "Other(s)" under G. The factors initally selected are for: measuring qualitatively the comparative costs (earth moving, A; habitat structures, B); water supply conditions (C); post-construction resistance to damage (stability, D); how long it would take to achieve a high degree of spawning or rearing productivity (relative time, E, e.g., compared to each other alternative); and probability of "success" (F), meaning how confident we are that each alternative will achieve and sustain an improved level of potential habitat compared to existing conditions. Other (G) factors which might be used are: the amount of (level of) habitat diversity created by each alternative, or the relative total amount of habitat created by each alternative by type needed, and/or just the total habitat Created.

There are a few basic operating rules for using this matrix approach to conduct a preliminary analysis of habitat improvement alternatives:

1. Do not constrain the solutions[3] by interjecting costs until the alternatives have been established, discussed and weighed. Even then the alternatives must be quantified before the costs are considered;

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[3] See first paragraph p. 5 and p. 6 of report by J.F. Orsborn, June 21, 1984. "An Evaluation of Plans for Habitat Improvements on Upper Dredged Area of Crooked River," Nez Perce National Forest.

Table 1. Conditions and Explanation of Terms (see text for more details)

Crooked River Habitat Improvements--Alternatives Matrix

AHL/WSU 10/84

AHL/WSU 10/84

Indices Factors To Consider	Alt. (1): Do Nothing	Alt. (2): Improve Habitat in Existing Channel	Alt. (3): Construct meander(s)		Alt. (4): Split Channels river and meander	Alt. (5): Backwater rearing areas (Compare 5A only with 5B)	
			A. Meander 1 With Habitat Improvement	B. Meander 2 With Habitat Improvement		A. Seepage flow Only	B. Small pipe flow from river
A. Earth Moving	None	Some, to install structures and modify channel.	Largest amount but cuts and fills can be balanced.	Less cut and fill than meander 1. Larger pond.	Earth moving would total Alt. (1) and (3A) or (3B).	Cut channel(s) from pond(s) downstream to river channel.	Some, extra to install supply pipe from river to pond(s).
B. Add Habitat Improvements	None	Only shade and a few poor structures available . . . . requires total flow control.	Shade and pools exist (some). Need to add all new features.	Other factors for Meander No. 2 are Similar to Meander No. 1.	Would have to add all improvements.	Would need to add diversity and stability to outlet channel(s).	Would enhance habitat year around and avoid trapping.
C. Surface and Groundwater Conditions	- FAST - Poor pool: riffle ratio → 0.	River on very steep slope at higher elevation than west ponds. G. W. drops rapidly.	New channel will intercept some G. W. flow. May have to seal.		Low flow is to low (15 cfs ±) to split.	Similar to now, but high flows would back into channels.	Design to use small amount during low flows. Enhances biology.
D. Stability of channel and Habitat Improvement	Poor-in transition to meander.	Run risk of high maintenance . . . stream still steep at high flows.	High stability because meander will be on more natural slope.		Poor in existing channel, good in meander(s).	Good stability, except for silt from backwater.	Would maintain flow path in channel and encourage faster vegetation growth.
E. Relative Time to Achieve High Productivity	Very long.	Much quicker than Alt. (1) depending on habitat improvements used.	Rapid increase depending on degree of improvement.		Same as each alternative in combined form.	Rapid, but would need some vegetation for shade.	Faster than 5A because water supplies certain year around.
F. Risk - or Probability of success.	High risk; or low probability of success.	Higher risk of damage to habitat improvement structures.	Some risk in terms of leakage but can be accounted for.		High risk of seepage loss and dry reaches in August and September.	High probability of rearing success. Does not provide spawning areas.	Better probability of success due to stability of water flow.
G. Other . . . such as Habitat Diversity							
Total Index	Sums for each alternative.						

Note: Indices range from 10 (best) to 0 (poorest) depending on the realtive level of each factor to each Alternative. (see example)
These indices are not quantifiable terms--they are relative to each other horizontally.

2. The index scale is applied horizontally for each factor, one at a time, by comparing the relatively "goodness" of each alternative against the others; the highest rating should be assigned first, then the lowest and then the intermediate ratings;
3. The objective of fisheries enhancement through habitat improvement structures (modifying the hydraulic geometry of the river channel), must be kept in mind (as well as longevity);
4. Several people[4] should read the qualitative assessment of conditions and terms in Table 1 to understand how we envision that each factor will relate to each alternative. The combined effects are evaluated when the total indices for each alternative are compared;
5. The same team of people should review our SAMPLE ANALYSIS in Table 2, keeping in mind that this analysis is from our perspective of the project, but that we followed the objective(s) in part (3) above;
6. Keep this principle of indices in mind: it is not the actual values of the indices which are important, but rather their differences among the alternatives.
7. In-depth discussion by the team of each factor, and how it relates to each alternative will help define the true (basic, real, natural) problems and thus generate the best solutions.
8. The habitat criteria provided by the Forest Service on 7/6/84 have been applied to the hydraulic design of the two alternative meanders; and also to Alternative & improving the existing river

[4] USFS and/or IDFG personnel.

Table 2. Sample Analysis---Use with Table 1---Explanation of Terms

	CROOKED RIVER HABITAT IMPROVEMENTS ALTERNATIVE MATRIX — For River Reach just north of airfield in Sec. 20, T28N, RGE.						Rated by: JFO	Date: 8/84
	FACTORS	ALT. (1): Do nothing	ALT. (2): Improve existing channel	ALT. (3): Construct meander(s)		ALT. (4): Split channels river plus meander	ALT. (5): Backwater rear areas (Compare 5A only with 5B)	
				A. Meander 1 with hab. impr.	B. Meander 2 with hab. impr.		A. Seepage flow only	B. Small pipe flow from river
A	Earth Moving	10	8	1	3	0	7	5
B	Add Habitat Improvements	10	2	3	4	3	5	10
C	Water Conditions surface and ground	1	7	8	9	2	5	8
D	Stability of channel and hab. Impr.	1	6	9	10	7	7[a]	8[b]
E	Relative time to achieve high productivity	1	7	8	9	7	8	10
F	Probability of success	1	8	8	8	4	2	9
G	Habitat Diversity	1	9	8	8	9[c]	6[d]	7[e]
	TOTAL INDEX	25	47	45	51	32	40	57

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a. 1 River; 9 Side Channel Combined.
b. 1 River; 10 Side Channel Combined.
c. Assumes Habitat Improvement in Both Channels.
d. Note: Factor D above assumes no improvements in river.
e. No River improvement.

channel. This assumes a high level of relative habitat improvement will be applied to both Alts. (2) and (3). Details on the meander designs are included in a later section on hydraulic design.

An explanation of the SAMPLE ANALYSIS (Table 2) follows.

Sample Analysis Of Alternatives

- Refer to Tables 1 and 2
- Alternatives 5A and 5B are only for rearing and can be compared only with each other, and Alternative 1, Do Nothing;5
- The split channel (Alternative No. 4) was included by request but should not be seriously considered because of: 1--the low flow in each split channel; and 2--the difficulty in maintaining two (2) viable channels.
- Comparison will be discussed in terms of ALTERNATIVES.
- When considering a factor for each alternative (as in the earth moving example above), select the alternatives with the 0 & 10 values, and then select the relative intermediate values of the index for the other alternatives.
- Considering the other factors for each alternative, the low and high values were selected and then the others were placed in their relative positions:

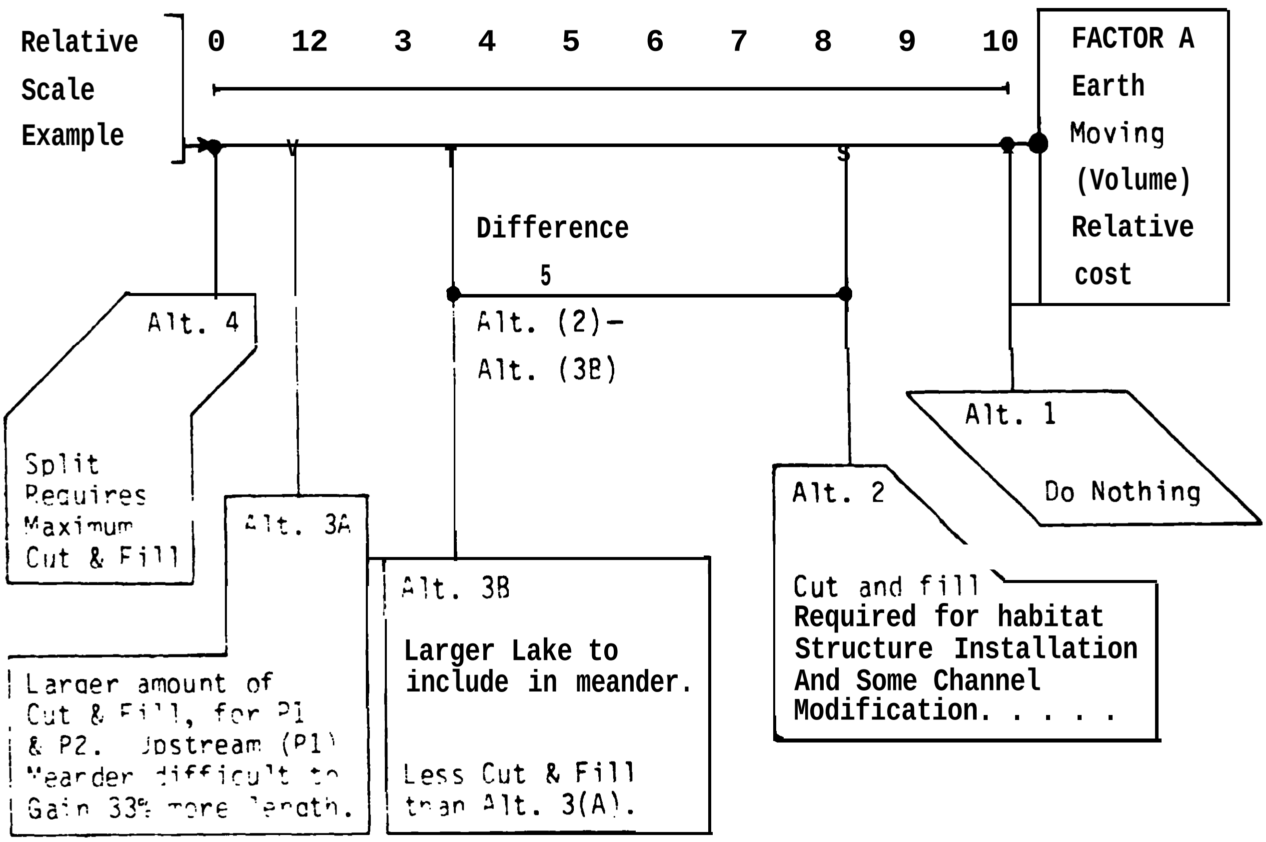
5 Alternative 5, Rearing Ponds, is included only for demonstration purposes, not as part of this year's meander pilot project.

EXAMPLE OF ANALYSIS OF ALTERNATIVES

- Refer to Tables 1 and 2
- Alternatives 5A and 5B are only for rearing and can be compared only with each other.
- The split channel (Alternative No. 4) was included by request but should not be seriously considered because of:
    1. The low flow in each split channel; and
    2. The difficulty in maintaining two (2) viable channels.
- Comparison will be discussed in terms of ALTERNATIVES.

See Table 2

1. Do Nothing	3A. Build upstream Meander #l
2. Improve the River	3B. Build downstream Meander #2



FACTOR	DISCUSSION FOR ALTS. l-2-3A-3B only
B. ADD HABITAT IMPROVEMENTS (drop structures shade, boulders, pools, riffles, cover, etc. . . .)	Nothing required in Alternate (l), but the Control of migration, spawning and rearing flows, was assumed for Alternatives 2 and 3B. The level of habitat improvement was assumed to be the same for each. But, the results in the existing river channel would not be as effective as in the meanders because of the steeper slope and instability in the existing channel.
C. SURFACE AND GROUNDWATER CONDITIONS Seepage gain and loss, depths, velocities, pools, riffles, utility.	Alt. (1) will leave the flow in the existing channel which is in an erratic state of transition while trying to meander, and has relatively little natural habitat. Meander 2 (on the P-2 survey line) will provide better flow-habitat conditions than Alts. 2 or 3A because of its better plan view geometry, its larger pond (No. 8), and the reduced volume of cut and fill.
D. STABILITY of both the modified channels and the habitat features.	As mentioned earlier the existing channel is on a steeper than natural gradient. Therefore, any habitat improvement will be in a less stable environment than in RESTORED MEANDERS 1 or 2 (Alts. 3A & 3B). Also, the meander plan, profile and cross-sections can be constructed for design flows more easily than the existing channel can be modified. More structures would be required in the existing channel to stabilize it than in a meander of longer length.

E. Relative TIME to achieve an increased level of Biological Productivity.	This is a function of how completely each alternative mimics natural habitat conditions for such a stream. The more diversity and stability of the habitat features, as well as the near-future hydrologic cycle, will govern how rapidly productivity rises.
F. PROBABILITY OF SUCCESS (+), AND OF RISK (-).	This will be a function of: (1) the amount of habitat improvements; (2) their diversity; (3) the water supply conditions; (4) channel and habitat improvement stabilities -- but there are other risk factors which include: (1) loss of part or all of the low flow in a new meander; (2) wash out of habitat features (loss of flow control & habitat continuity); or (3) an extreme flow (flood event like 1964) which could abandon the existing channel or a meander. The potential seepage loss can be managed through proper design and construction, and damage potential can be minimized.
G. OTHER FACTORS	Could be developed as discussions proceed, and could include factors such as: (1) the relative amount of habitat increase above the existing level in the river channel; or (2) an index of habitat diversity for each alternative.

Based on our analysis, we would recommend Alt. 3(B) as the most promising alternative to construct a "pilot" meander to compare with habitat improvements upstream beside the airfield, and with the baseline reaches. But, we recommend that the Agency Team conduct its own evaluation using the Decision Matrix method.

The basic differences in initial costs between enhancing the existing channel with habitat improvments, and building one or both meander channels, is in the extra cost of cut and fill in the meanders, assuming the same level of habitat improvement in each alternative. When conducting your assessment of the alternatives you may wish to use some different factors which you feel are more important. The indices are not fixed!

The methodology should probably be applied by say three or more individuals, and their results compared, discussed and justified.

Then, you can make a cost estimate of habitat improvements and earth moving and compare the costs of the alternatives to available funds. The highest level of improvement should Se planned, and then staged, so that the best long-range results are achieved.

NOTE : Following review of the preliminary report the Forest Service indicated a preference for planning to construct both meanders. Consideration will continue through the winter.

III. GENERAL SITE CONDITIONS

The Crooked River project area is located in central Idaho, southwest of Elk City on U.S. Forest Service Road 233 (SW 1/4, NW 1/4, Sec. 30, T28N, R8E,). The site covers an area of approximately 850,000 square feet within the Crooked River Basin. Crooked River is a tributary of the South Fork of the Clearwater River (Figure 1).

During the 1940's and 1950's the site was dredged for gold, disrupting much of the natural stream habitat. Piles of reworked cobble, gravel, sand and silt create a combination of mounds and depressions throughout the site. These surface deposits are mostly coarse gravel and boulders that were brought to the surface during the dredging process. Pines and other pioneer vegetation have started to grow throughout the site, though there are still large sections with no vegetative cover.

As a consequence of the dredging Crooked River was pushed to the east side of the stream valley against a steep side hill. The river is currently forced to flow down a relatively straight channel, restricting the development of natural habitat. Also located on the site are a series of ponds hydraulically connected to each other and to the river through subsurface flow. On the west side of the site six of these ponds form a line approximately parallel to the stream beside Forest Road 233.

The purpose of this study is to consider ways in which this section of Crooked River could be "normalized" into a state more conducive to the restoration of fish and wildlife resources. In order to do this, two preliminary meander patterns have been developed. These meanders were laid out based on the existing meander patterns, pond locations, topography, vegetation, desired habitat features and hydraulic constraints.

In the next chapter the methods of data collection and interpretation of this data for both the land and water are discussed. This is followed by the analysis of the hydrologic system and estimation of low, average and flood flows for Crooked River. The actual meander designs are developed in the following chapter of the report.

IV. DATA COLLECTION AND INTERPRETATION OF EXISTING LAND SURFACE CONDITIONS

On July 3-6, July 20, August 2, and October 19-20, 1984 topographic surveys were completed on the Crooked River study area. Ground controls of the topographic survey are shown on the map (Drawings A-C) attached at the back. Figure 3 shows these two basic loops as well as the location of a series of temporary bench marks and a permanent baseline that were used for the initiation of additional survey work. All elevations determined in this survey are established relative to an arbitrary elevation of 1,000 feet at BM #1. Between August 2 and October 19 irresponsible person(s) removed all but 4 control points and threw most of the survey stakes and staff gages in the river. A majority of the time on October 19-20 had to be spent in reestablishing the control system before the two final meander alignments could be established. These new alignments are discussed in detail in the section on meander design, and in Appendix II.

The major purpose of these surveys was to lay out two lines, called Pl and P2, (P-lines), which approximate the location of possible meanders (Figure 2). Due to the exremely variable topography of the site, one of the first activities of the field survey was to walk these proposed meander routes and document the field conditions. The establishment of the initial "P-lines" was aided by indentification of:

- natural take-off locations (stations 0+00) for the meander departure points along Crooked River;
- natural tangent locations where the meanders could rejoin Crooked River at an acute angle;

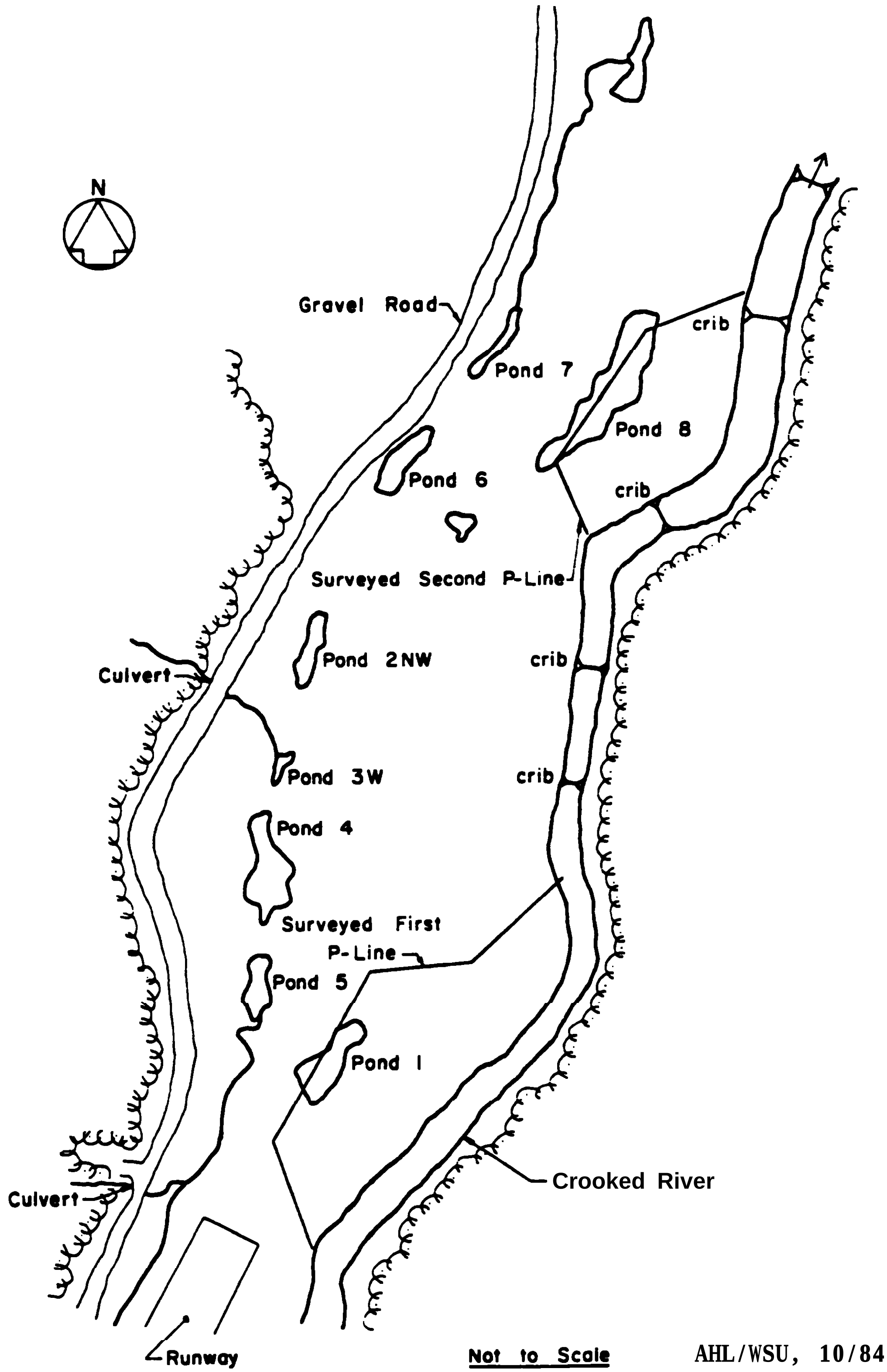
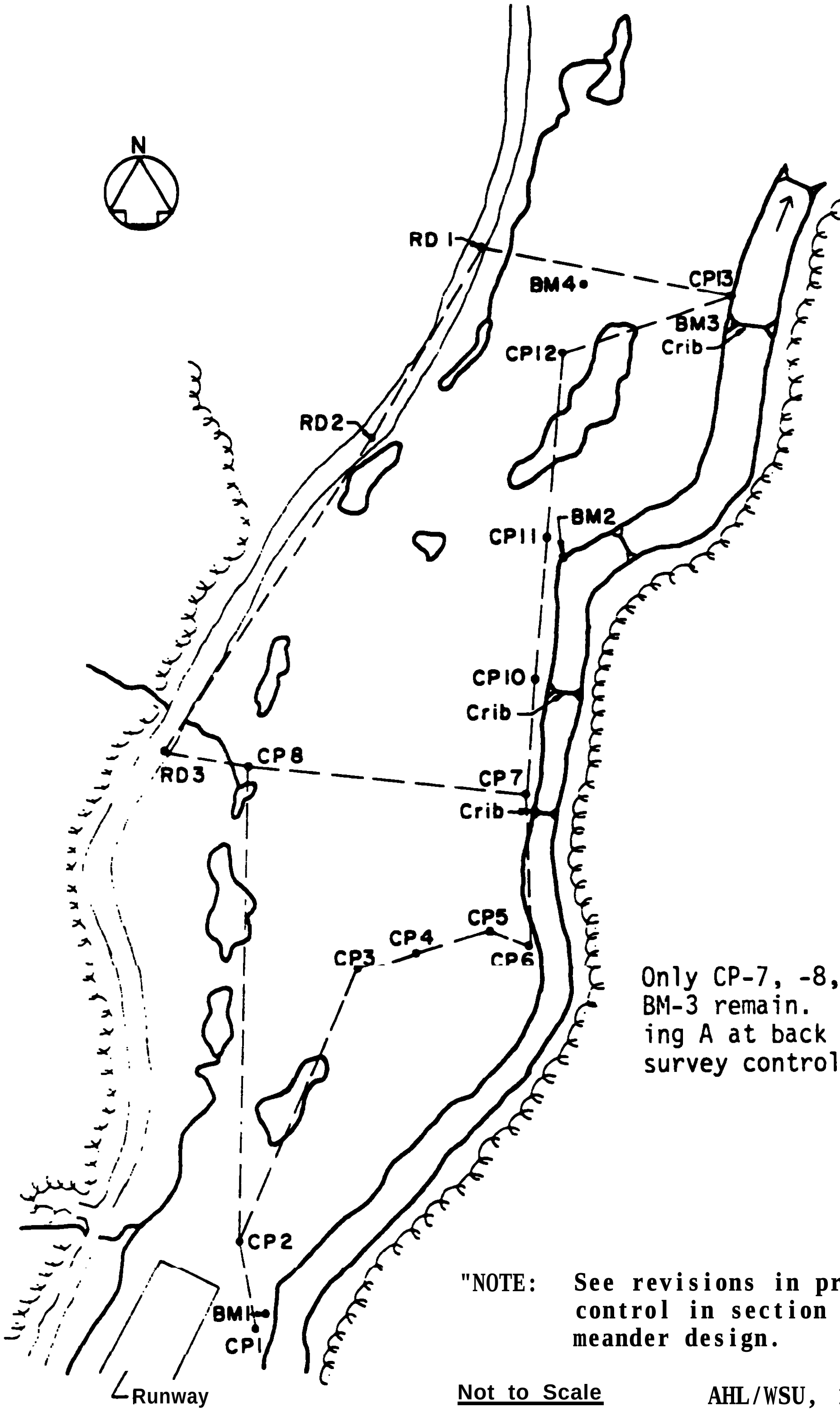


Figure 2. Pond and Surveyed P-Line Layouts.



Only CP-7, -8, -10, and BM-3 remain. See Drawing A at back for final survey controls.

"NOTE: See revisions in project control in section on meander design.

Not to Scale

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Figure 3. Transit Control Loop Locations and Bench Mark Locations.

- existing ponds and depressions that could accomodate the new channel, thus reducing some of the cut and fill requirements; and
- existing trees that could lend "instant" habitat enhancement along the new channel.

Level loops were done to verify elevations at stations and controls and establish benchmarks along the P-lines. Stations were chosen every 50 feet, or where there was a major change in direction or a break in grade. Elevations on either side of the P-lines were determined in transects using a hand level. Using these elevations, a series of cross sections were made at each station along Pl and P2. These cross sections were later used to estimate the amount of cut and fill for the construction of the meanders and to help finalize the grade and shape of the meander channels.

Results of the field survey along P-lines are presented in Appendix II at the back of the report as are three maps of the study site. Predominant tree clusters, ponds and the existing river layout were considered for each meander site. The recommended survey lines (P-lines) and channel centerline are sketched with regard to the existing topographic features and in accordance with hydraulic design requirements.

Additional documentation of the upstream survey line with photographs taken at stations along the survey line looking "downstream" were presented with the preliminary report. The photographs were referenced to a map of the survey line to permit the reader to "walk" the proposed upstream route (P-l).

V. LOCAL SURFACE AND GROUNDWATER

The location and elevation of the major ponds and of the stream edge were found by a series of side shots from the main transit control loops. A series of nine staff gages were then placed in the ponds and another one in the stream itself to monitor changes in the water levels over a time. Figure 4 shows the location of these staff gages and Table 3 records the readings. It should be noted that the readings are only relative to the reference elevation of 1,000 feet at BM #1 and indicate water surface elevations, not actual stream or pond depths. Table 4 is an index to Crooked River water surface elevations. Locations are recorded on the map at the back of the report.

Figure 5 shows a profile through ponds 5-7 on the west side of the study area. The major source of water for these ponds are small streams from the west side of the watershed, surface runoff, and Interflow from Crooked River. During the period of this study the first two sources were minimal, indicating that ground water from the river valley deposits is the major contributor. At the south ends of ponds 4-7 around water seepage was observed, indicating a direct hydraulic connection between ponds. The average hydraulic gradient was found to be 0.024. Variation from this gradient could be due to a pond having additional sources of recharge or discharge, thus changing the elevation head between ponds.

A series of electrical conductivity and temperature measurements were made in the stream and in the ponds. Due to the relatively clean porous nature of the gravel deposits similar conductivity and temperature values would be expected. If the ponds were being fed by a deeper ground water

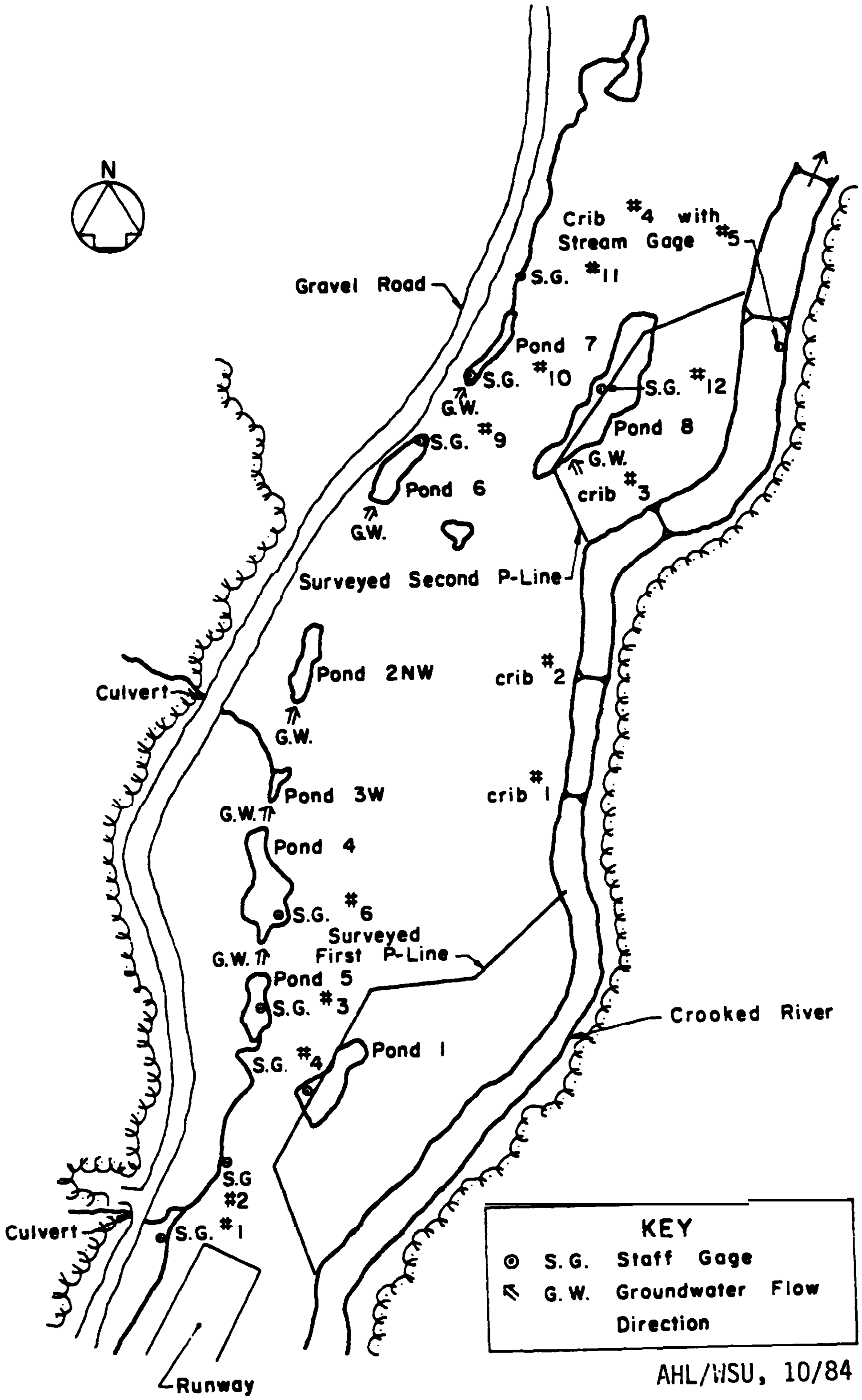

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Figure 4. Staff Gage Locations.

Table 3. Staff Gage Data for Crooked River Project

Washington State University/Elk City Ranger District

Staff Gage Number	Rate of Reading and Water Surface Elevations[1] July 6, 1984	July 20, 1984	August 23, 1984
1	994.05 ft.	993.35 ft.	993.44 ft.
2	988.49	988.45	988.45
3	985.66	984.36	no record
4	986.33	986.05	overgage
5	975.15	974.48	no record
6		983.15	983.34
7	not installed	not installed	not installed
8			
9		978.10	978.15
10		975.03	975.02
11		974.88	974.86
12		975.47	975.42

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1 Elevations are relative to a benchmark established as 1,000.00 ft., located at the south end of the project near the north end of the airstrip.

Table 4. Index to Water Surface Elevations, Crooked River, Idaho

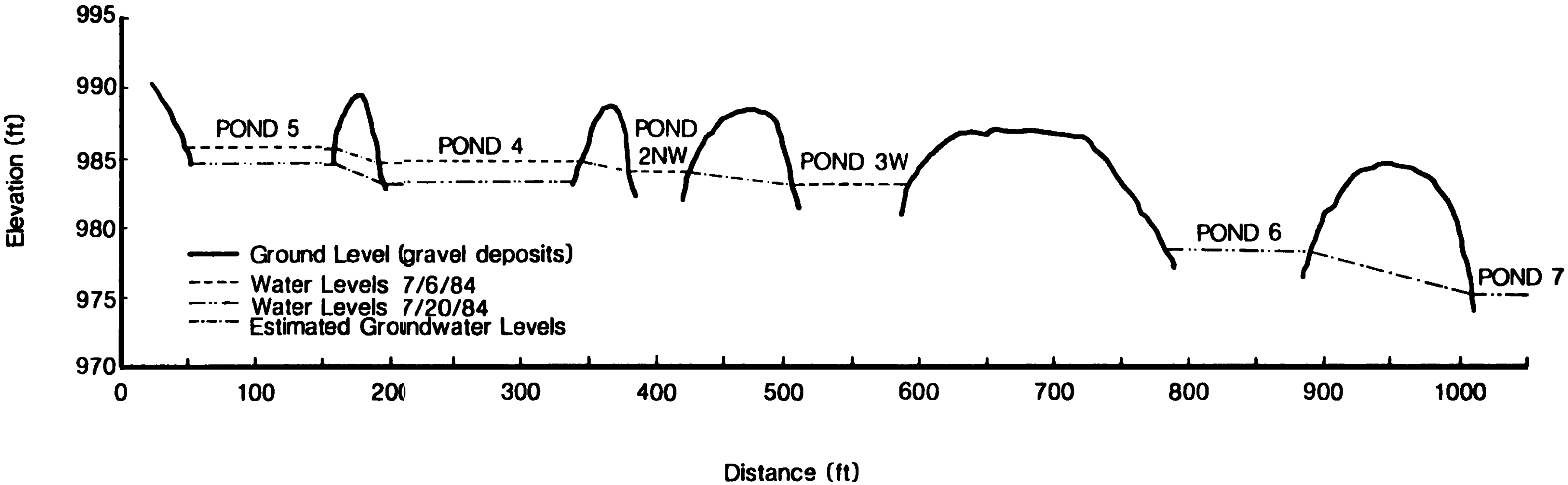
Date	Original WSE Number	New WSE Number[1]	Reference Elevation[2]
7/4/84	No field number 1	Deleted	--
7/4/84	WS2	WS1	994.29
7/4/84	WS3	WS2	993.94
7/4/84	WS4	WS3	992.58
7/4/84	WS5	WS4	992.28
7/4/84	WS6	WS5	991.58
7/5/84	WS1	WS6	987.53
7/5/84	WS2	WS7	986.63
7/5/84	WS3	WS8	985.83
7/5/84	WS4	WS9	985.28
7/5/84	WS5	WS10	984.93
7/5/84	WS6	WS11	984.63
7/5/84	WS7	WS12	984.23
7/5/84	WS8	WS13	984.08
7/5/84	WS9	WS14	984.03
7/5/84	WS10	WS15	982.33
7/5/84	WS11	WS16	983.13
7/5/84	WS12	WS17	982.53
7/5/84	WS13	WS18	981.93
8/2/84	WS2	WS18	979.68
7/5/84	WS14	WS19	980.08
8/2/84	WS1	WS19	981.75
8/2/84	WS3	WS20	979.67
8/2/84	WS4	WS21	979.00
8/2/84	WS5	WS22	978.55
8/2/84	WS6	WS23	977.67
8/2/84	WS7	WS24	977.17
7/20/84	WS8	WS25	973.45

1 Stations number from South to North in direction of flow.

2 Elevations referred to TBM, NE of Runway, Elevation 1000.0.

AHL/WSU 10/84.

FIGURE 5 **PROFILE SECTION OF PONDS 5-7**



NOTE: Invert elevations of Ponds not surveyed.

aquifer the values of conductivity would be much higher since the ground water would have been in contact with more dissolved ions. Also, the temperature would be warmer. Table 5 shows the conductivity and temperature values at various locations. As expected, the pond and streams have similar values with the ponds being slightly higher. This indicates that the ponds and streams are all directly connected and makeup a shallow ground water flow system.

The stream elevations are generally one to two feet higher than the corresponding pond elevations. Therefore, the stream is recharging the ground water supply or is an influent stream. This is confirmed by direct observation of ground water seepage on the south east side of pond 8 where the stream flow is directed toward the pond before it starts to meander to the east (Figure 4). Since the stream was, at the time of this study, approaching its low flow period, it can be expected that it recharges the ground water year round.

In addition to staff gages for measuring water levels in the ponds, the stream was gaged just upstream of crib #4 to measure flow changes. Figure 6 is a plot of flow (Q) versus time (t). As the plot indicates, flows on July 20 and August 2 were nearly the same. This could be due to a series of large rain storms occuring through the last week of July. A plot of Q versus staff gage readings was made as a basic calibration curve, allowing flow determination directly from the staff reading. Flow measurements were also made on July 6, on the small stream on the west side of the site that feeds pond 5. The stream flow was found to be about 4 cubic feet per second. On the later field trips this flow was approaching zero, but in October it had increased due to early snowmelt.

Table 5. Water Conductivity And Water Temperature Values At The Crooked River Site on July 4, 1984

Location	Conductivity (umhos)	Temperature (°C)
Near S.G. #1	23	11
South Culvert	32	11
Near S.G. #2	25	10
Pond #5 (South End)	29	10
Pond #5 (North End)	22	10
Pond #3W (South End)	26	11
Pond #3W (North End)	27	11
Pond #l	22	10
Near CP6 - Stream	18	9
Near BM3 - Stream	18	10

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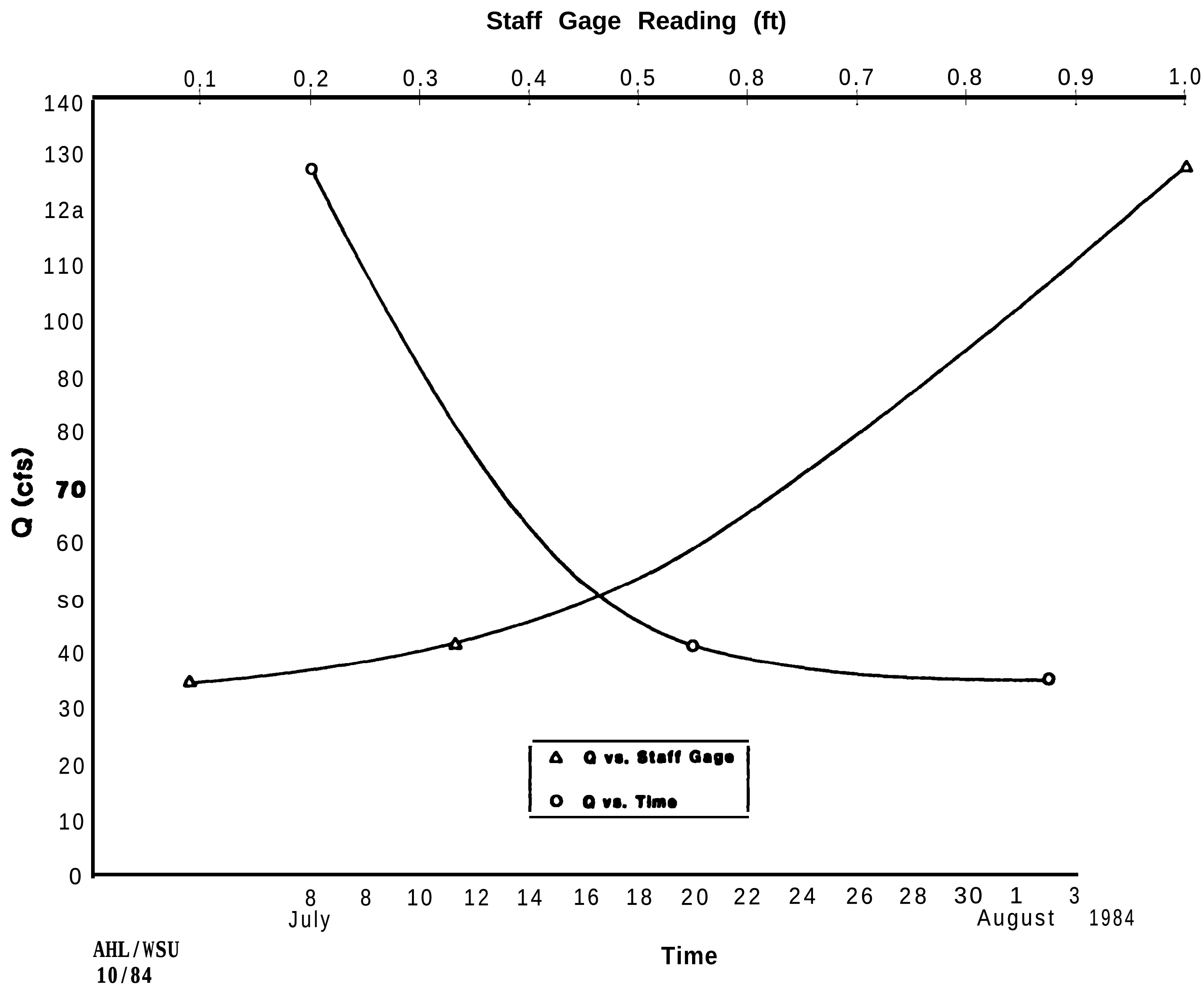


Figure 6. Staff Gage #5 Flow Calibration Curve, Crooked River, Idaho.

VI. HYDROLOGIC ANALYSIS

Methods

This chapter explains methods for determining low, average and flood flows for the Crooked River study area. The relationships used to determine these flows have been developed in four previous studies:

1. Relationships of low, average and flood flows for streams in the Pacific Northwest (Orsborn, 1975a).
2. Surface water resources of the Coeur D'Alene, St. Joe and St. Maries rivers in northern Idaho (Orsborn, 1975b).
3. Magnitude and frequency of floods in small drainage basins in Idaho (Thomas, 1973).
4. Relationships among streamflow, drainage basin and channel characteristics (Tsang, 1980).

Based on parameters such as precipitation, differential basin elevation, stream length, and basin drainage area, these reports contain a series of relationships for determining streamflow characteristics. Combinations of these relationships have been applied in this report to estimate the low, average and flood flows of Crooked River.

Available Information

Precipitation

The average precipitation for the Crooked River area was found to be approximately 50 inches per year. This information was taken from a U.S.

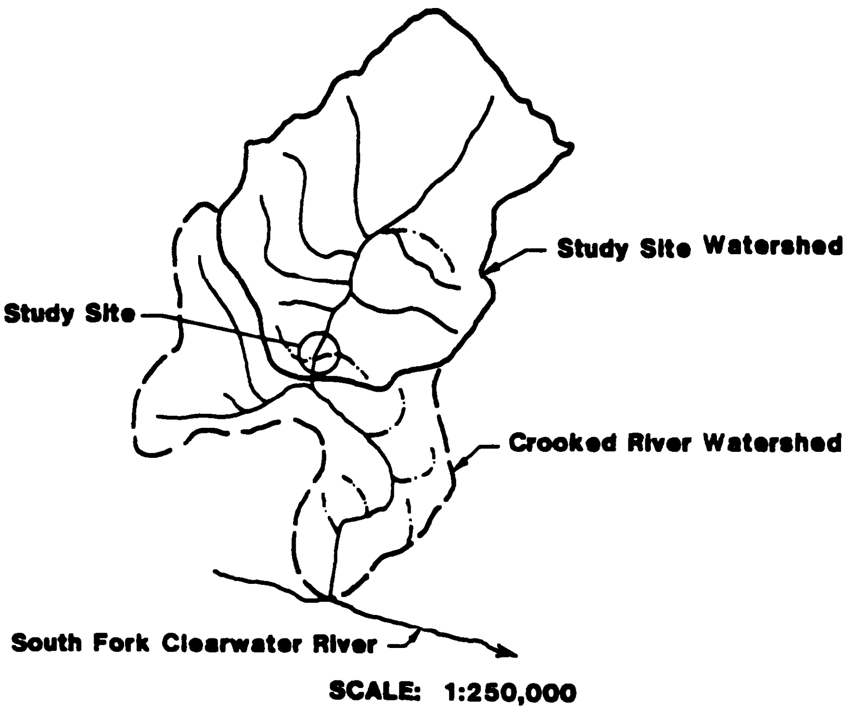
Weather Service precipitation map of Idaho and confirmed by the Nez Perce Forest hydrologist. This average precipitation is similar to precipitation records for the Coeur D'Alene area (Orsborn, 1975b).

Basin Characteristics

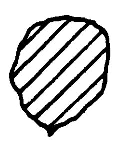
Basin characteristics (drainage area, differential elevation, and total stream length) for the Crooked River basin were collected from U.S. Geological Survey topographic maps (1:24,000 and 1:250,000). Differential elevation (H) for the basin was determined to be 0.47 miles. This elevation, taken from the 1:24,000 scale map, is a measure of the difference between the upper headwater elevation (longest continuous contour line at the headwaters), and the base elevation at the site (Figure 7). Drainage area (A) for the Crooked River basin extends from the north edge of the study site, upstream to the watershed divide. The 42 square mile area was determined with an electronic digitizer from 1:24,000 scale topographic maps. Total stream length (LS) was digitized from the same maps and found to be 84 miles. To measure the stream lengths, an assumption was made that streams depicted as intermittent on the map (dashed blue lines) were actually perennial. Previous field experience of the authors has indicated that dense cover in the forested areas typically inhibits photogrammetric efforts to map the streams in their entirety. Time constraints precluded a thorough field evaluation of the actual length of the streams.

In order to check the basin characteristics' hydrologic relationships determined in the Coeur D'Alene study were used (Orsborn 1975b). Map data showed a relationship of stream length to drainage area of LS = 2.0(A). The same relationship for the Coeur D'Alene basin was LS = 1.4(A). To assume that the Crooked River is similar to the Coeur D'Alene basin (due to

CROOKED RIVER STUDY BASIN



Available Information

Watershed Parameter	TOTAL STREAM LENGTH LS : 59;84 mi.	BASIN AREA AB=42 mi.^{2}	BASIN RELIEF HB: 0.47 mi.
Geometric Description			

AHL/WSU, 10/84 NOTE: **Precipitation ≈50 in/yr**

Figure 7. Crooked River Study Site.

similar basin characteristics and climatic data) would yield a total stream length (LS) of 59 miles, as opposed to the 84 miles measured from the map. This discrepancy is the result of an uncertainty in the percentage of intermittent to perennial streams on the topographic maps used. Therefore, both values for total stream length were used to give a range of values for estimating streamflows.

Estimation of Flows

Streamflow estimates were calculated using relationships developed in the four studies mentioned previously and have been summarized in Table 6. In all calculations involving stream lengths, two values of total stream length (LS) were used. The value of 84 miles was measured directly from a topographic map and the value of 59 miles was derived from relationships developed in the Coeur D'Alene study.

Average annual flow (QAA), or the mean of all annual mean flows for the period of record, was calculated two different ways. In the first method (Table 6; Relationship 1) Tsang correlated basin geomorphic parameters with characteristic streamflows in the St. Maries River basin in northern Idaho (Tsang, 1980). Average annual flow (QAA) has also been determined using such parameters as: average annual precipitation (P), drainage area (A), and a regional coefficient ranging from 0.045 to 0.060 for this particular hydrologic province (Orsborn, 1975b). Relationships 2 and 3 (Table 6) determine QAA using the two ranges of coefficients, whereas relationship 4 uses an averaged coefficient. The average annual flow, determined in relationship 4 to be 110 cfs, will be used as the average value.

Table 6. Summary of Flow Estimates, Crooked River Restoration Site

NO.	FLOW SYMBOL	RELATIONSHIP	LOCATION (BASIN)	SOURCE	FLOW ESTIMATES (cfs) LS = 59 mi	LS = 84 mi
1	QAA	$QAA = 1.40\ (LS)$	St. Maries	Tsang 1980	83	118
2	QAA	$QAA = 0.045\ (P \cdot A)$	Coeur D'Alene	Orsborn 1975b	94	94
3	QAA	$QAA = 0.06\ (P \cdot A)$	Coeur D'Alene	Orsborn 1975b	126	126
4	QAA*	$QAA = 0.052\ (P \cdot A)$	Coeur D'Alene	Orsborn 1975b	110	110
5	Q7L2	$Q7L2 = 0.32\ (LS)(H)^{1/2}$	Coeur D'Alene	Orsborn 1975b	13	18
6	Q7L20	$Q7L20 = \frac{0.20}{0.32}(Q7L2)$	Coeur D'Alene	Orsborn 1975b	8	12
7	QF2P	$QF2P = 1000\left[\frac{QAA^*}{51(Q7L2)^{.34}}\right]^{1.5}$	Clearwater	Orsborn 1975a	856	725
8	QF50P	$QF50P = 1000\left[\frac{QAA^*}{21.6(Q7L2)^{0.36}}\right]^{1.4}$	Clearwater	Orsborn 1975a	2681	2275
9	QF2P	$QF2P = 6.31\left[\frac{QAA^*}{(Q7L2)^{0.37}}\right]^{1.35}$	Coeur D'Alene	Orsborn 1975b	999	849

*Use QAA = 110 CFS, Average Annual Flow

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Two different low flows were calculated, the 'I-day average low flow with a two-year recurrence interval (Q7L2), and a 7-day average low flow with a twenty-year recurrence interval (Q7L20). These flows were determined with relationships developed in the Coeur D'Alene basin study using total stream length (LS) and differential elevation (H) (Table 6; Relationships 5,6).

The two types of flood flows estimated (Table 6; Relationships 7,8,9) were the instantaneous peak floods with a recurrence interval of two years, based on an annual peak flood series (QF2P), and the instantaneous peak flood with a recurrence interval of fifty years (QF50P). The relationships for these estimates were developed as a regional hydrologic model for the Clearwater basin (Province 2) in Idaho (Orsborn, 1975a). Also, QF2P was calculated using the Coeur D'Alene study (Orsborn, 1975b) resulting in much higher flows. For all three calculations, a value of 110 cfs was used for average annual flow, (QAA).

Average Annual Flow (QAA)

The estimates for average annual flow ranged from 83 to 126 cfs. The value obtained using the averaged coefficient for the Coeur D'Alene study (Table 6; Relationship 4) was 110 cfs. This value was to be used as a first estimate. In order to obtain a range of values for average annual flow, flow records for a typical wet year (1972) and a typical dry year (1973) for the Coeur D'Alene basin were examined (USGS, 1973-1974). A relationship between the average annual flow for the year, and the average annual flow calculated over the period of record was found for 1973 and 1974 to be:

Average annual flow in wet year (1972)	1.35(QAA)
Average annual flow in dry year (1973)	0.50(QAA)

The coefficients of 1.35 for 1972 and 0.50 for 1973 found for the Coeur D'Alene basin are very similar to those found for two representative gaging stations located near the study site of Crooked River (Figure 8). The station on the South Fork of the Clearwater River near Elk City, Idaho (13338500) shows coefficients of 1.36 for 1972 and 0.49 for 1973. The station on the Lochsa River near Lowell, Idaho (13337000) has slightly higher coefficients of 1.48 for 1972 and 0.58 for 1973. This can be attributed to its higher elevation. Therefore, using the relationships found in the Coeur D'Alene basin, the range of average annual flow values (QAA) for Crooked River has been estimated to be 55 cfs to 150 cfs.

To confirm the first estimate of average annual flow,(QAA) for Crooked River, U.S. Forest Service miscellaneous discharge measurements taken at a station near the mouth of the Crooked River, have been compared to corresponding daily flows for stations on the Lochsa and the Clearwater (Table 7, Figure 8, USGS, 1979-1980). A graph of the Crooked River miscellaneous measurements versus corresponding daily flows on the Lochsa and the Clearwater show a direct relationship on log-log paper (Figure 9). There are a few measurements that do not seem to fit the trend. These measurements were taken during the rising limb of the hydrograph which predictably would not show a good flow correlation due to the variability of streamflows during initial seasonal runoff. Better correlations typically occur during the falling limb of a particular hydrograph when streamflows have less variablility. With flow relationships between the three rivers established, average discharge for the period of record (through water year 1980) for the Clearwater and Lochsa were located on the graph, and the corresponding average annual flow for the Crooked River station was found. In order to relate the flow values at the mouth

Table 7. Miscellaneous Discharge Measurements

Date	Crooked River[1] Discharge (cfs)	Lochsa Discharge (cfs)	S.F. Clearwater[3] Discharge (cfs)
5/24/79	695	19400	4760
6/06/79	181	10400	2150
7/19/79	48	1070	318
5/26/80	308	8610	5350
6/03/80	533	7980	3720
6/11/80	413	8740	2770
6/19/80	444	7130	2600
6/24/80	288	4550	1970
7/30/80	53	901	460

(1) Crooked River Station, near mouth SE 1/4 NE 1/4, Sect. 25, T29N, R7E (CSFS measurements).

(2) Lochsa river near Lowell, Idaho 613337000 Drainage area = 1180 mi^2 (USGS, 1979-1980).

(3) South Fork Clearwater at Stites, Idaho #13338500 Drainage area = 1150 mi^2 (USGS, 1979-1980).

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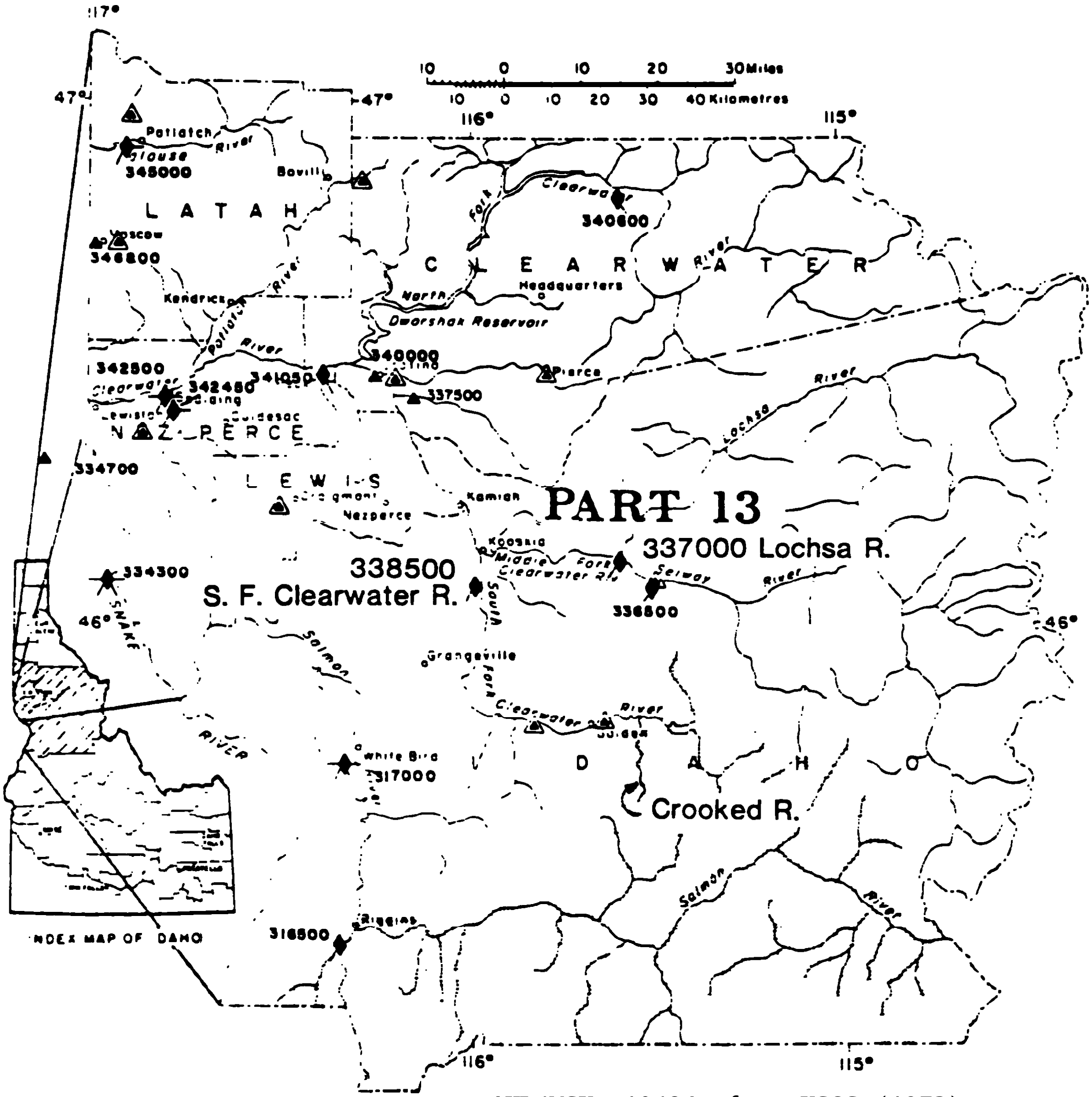

AHL/WSU, 10/84 after USGS (1973)

Figure 8. Location of Representative Gaging Stations.

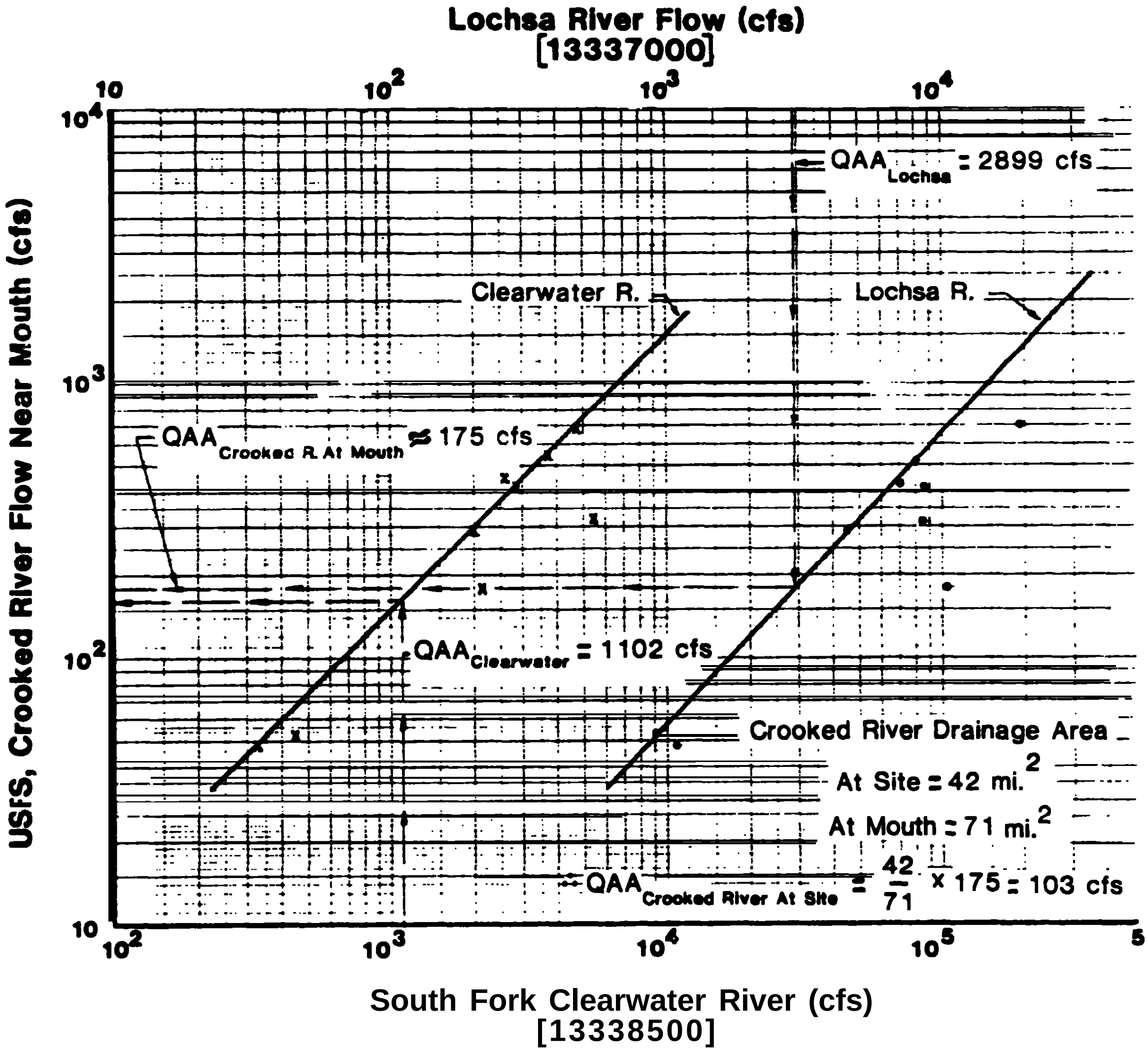

Figure 9. Correlations of USFS Crooked River Flow Data to Daily Flows on Lochsa and Clearwater Rivers.

(Drainage Area = 71 sq. miles), to the flows at the site (Drainage area = 42 sq. miles), the QAA for the Crooked River station was multiplied by the factor of (42/71). This gave an average annual flow (QAA) of approximately 103 cfs which reinforces the first estimate of 110 cfs.

Low Flows

The range of estimated flows for Q7L2 was from 13 to 18 cfs (depending on the stream length used) with an average of 15 cfs (Table 6; Relationship 5). The range of flows for Q7L20 was between 8 and 12 cfs with an average of 10 cfs. As a check on these estimates, a seven-day average low flow recurrence interval graph was drawn (Figure 10). The slope is very close to the slope resulting from flow measurements on the Coeur d'Alene River above Shoshone Creek (Orsborn, 1975b). The Coeur d'Alene River above Shoshone Creek is similar to Crooked River in precipitation and its low flow recurrence interval graph slope of 0.19 verifies the estimate of low flows for Crooked River shown in Figure 10.

Flood Flows

As mentioned previously, two methods were used (Table 6; Relationship 7 and 9) to estimate the instantaneous peak flood with a recurrence interval of 2 years (QF2P). Both relationships involved QAA and Q7L2 where Q7L2 varied from 13 to 18 cfs. If 110 cfs is used for average annual flow (QAA) and an average Q7L2 of 15 cfs is used, the average flood flow (QF2P) ranges from 830 to 1075 cfs. The first average estimate then was chosen to be 1,000 cfs. The value of the 50-year flood (QF50P) was previously estimated to range between 2,275 to 2,681 cfs (Table 6; Relationship 8). Using another regional relationship developed for Province 2 of Idaho in

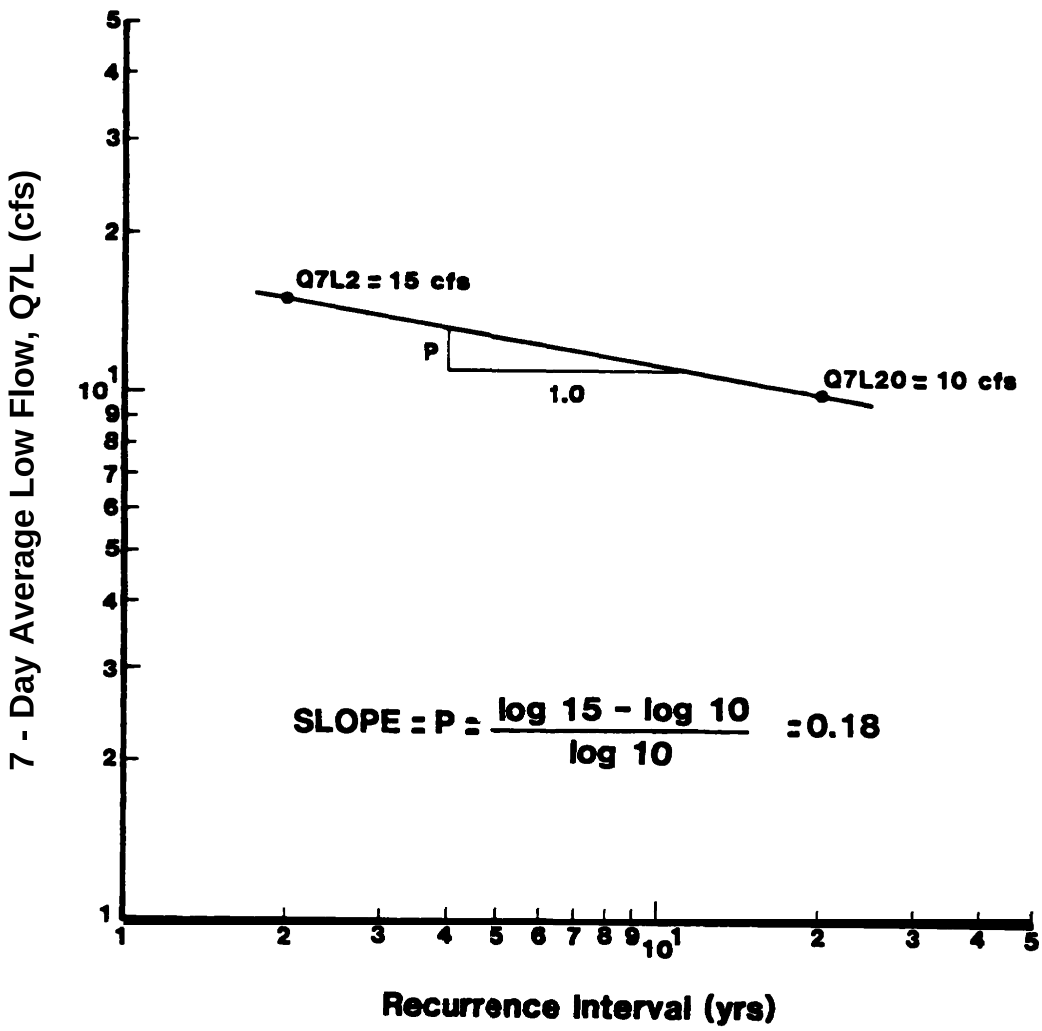

Figure 10. 7-Day Average Low Flow Recurrence Interval Graph. Estimated for Crooked River Restoration Site.

the Pacific Northwest report where QF5OP = 2(QF2P), the 50-year peak flood would be about 2,000 cfs (Orsborn, 1975a). This value will be used for the upper design flow estimate.

Maximum daily flow (QFD) can be related to the 50-year peak flood flow (QF50P) using relationships developed for Maximum Daily and Instantaneous Peak Floods for Oregon provinces: $QFD = 1.2(QFP)^{0.95}$ (Orsborn, 1975a). Assuming the maximum daily flow (QFD) occurs on the same day as the instantaneous peak flood[6] with a 50-year recurrence interval (QF50P), maximum daily flow (QFD) is determined to be about 1800 cfs.

To confirm these estimates of QF2P and QF50P, data containing 2-year floods and maximum of record floods for the Clearwater, Spokane, and Kootenai River basins were analyzed (Table 8). A graph was drawn of flood discharges (2-year and maximum of record) versus drainage area (Figure 11). The graph shows that Crooked River, with a drainage area of 42 sq. miles, should have an average flood (QF2P) of approximately 1000 cfs and a maximum flood of 2,200 cfs, which approximate the first estimates of QF2P and QF50P.

With these estimates confirmed, a flood frequency curve can be drawn (Figure 12). The peak flood flow with a 100-year recurrence interval (QF100P) read from the graph would be approximately 2,700 cfs.

Duration Curve Estimate

Using the flows estimated previously, a duration curve was developed (Figure 13). Average daily flow at the site is graphed against the percentage of time the flow is equalled or exceeded. To plot our estimations it is assumed that the maximum flow or 50-year flood in this case is equalled or exceeded approximately zero percent of the time, the

6 True for greater than 95% of the events.

Table 8. Flood Discharges For Clearwater, Spokane, and Kootenai River Basins
Data from References (3), (5) and (6).

Station Number	Station Name	Drainage Area (mi^2)	2-Year Flood (cfs)	Maximum Of Record (cfs)
Clearwater River Basin				
13335420	Selway River	211.00		3700
13336600	Swiftwater Creek	6.19	83	150
13336650	E. Fk. Papoose Crrek	4.51	77	125
13336800	Warm Springs	74.70		2260
13336850	Weir Creek	12.20	270	470
13337200	Red Horse Creek	9.13	92	200
13338200	Sally Ann Creek	13.90	191	305
13339700	Canal Gulch Creek	5.90	112	291
13339900	Deer Creek	6.80	79	485
13341140	Big Canyon Creek	22.50		8360
13341300	Bloom Creek	3.15	51	151
13341400	E. Fk. Potlatch River	41.60	610	1740
Spokane River Basin				
12411800	E. Fk Eagle Creek	9.13		457
12412120	Canyon Creek	18.10		817
12413450	Pine Creek	74.00		5290
12413470	S. Fk. Coeur d'Alene R.	310.00		9440
12413700	Latour Cr. Near Cataldo	24.80		1400
12413950	N. Fk. St. Joe River	111.00		3500
Kootenai River Basin				
12313000	Myrtle Creek	37.00		1260
12305500	Boulder Creek	53.00		2720

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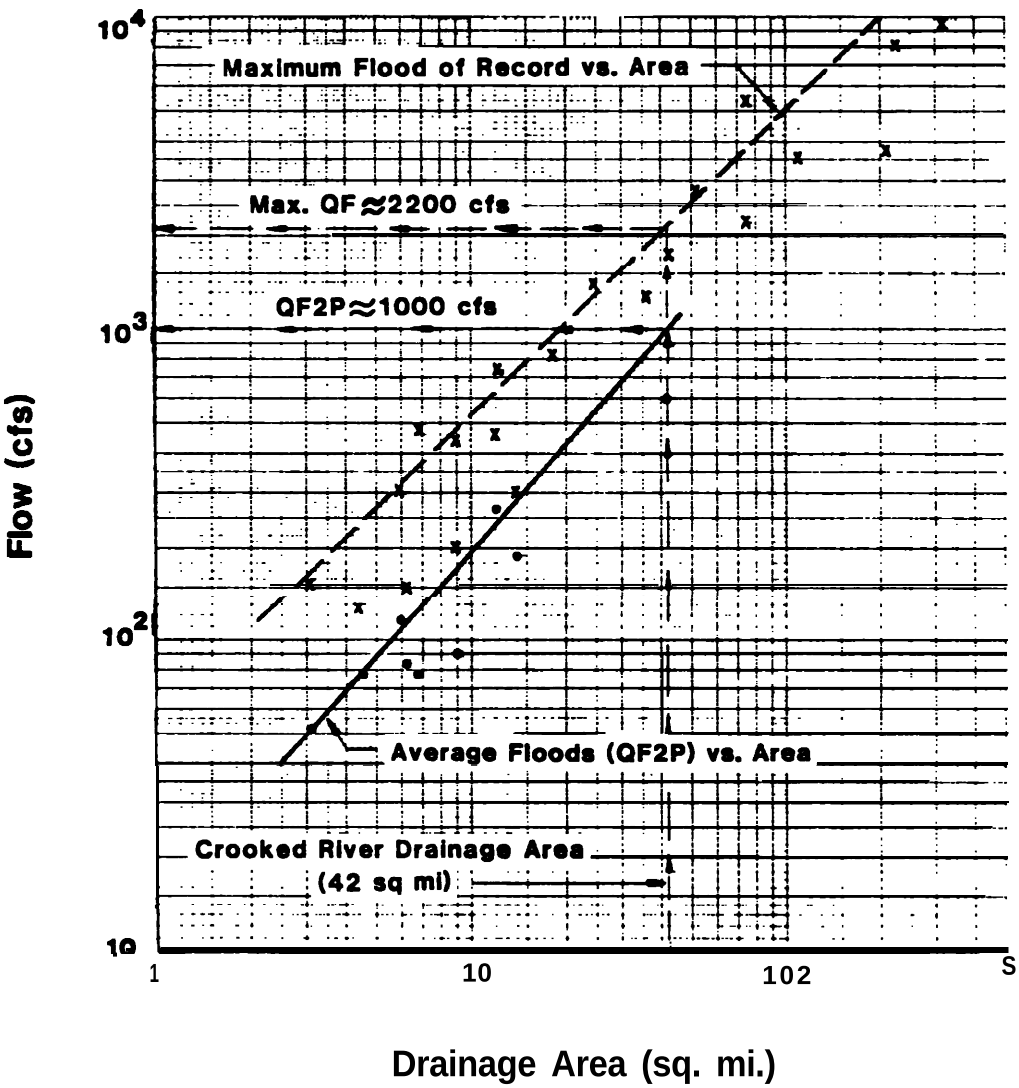

Figure 11. Flood Discharge Versus Drainage Area for Clearwater, Spokane, and Kootenai River Basins.

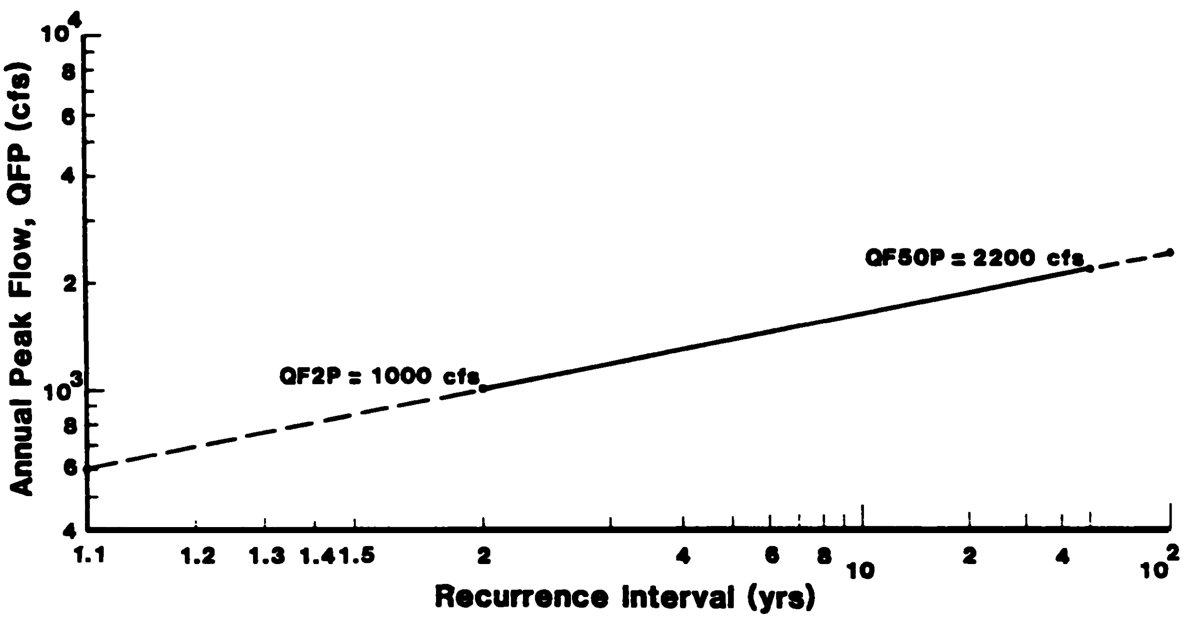

Figure 12. Crooked River Estimated Flood Frequency Curve at the Restoration Site.

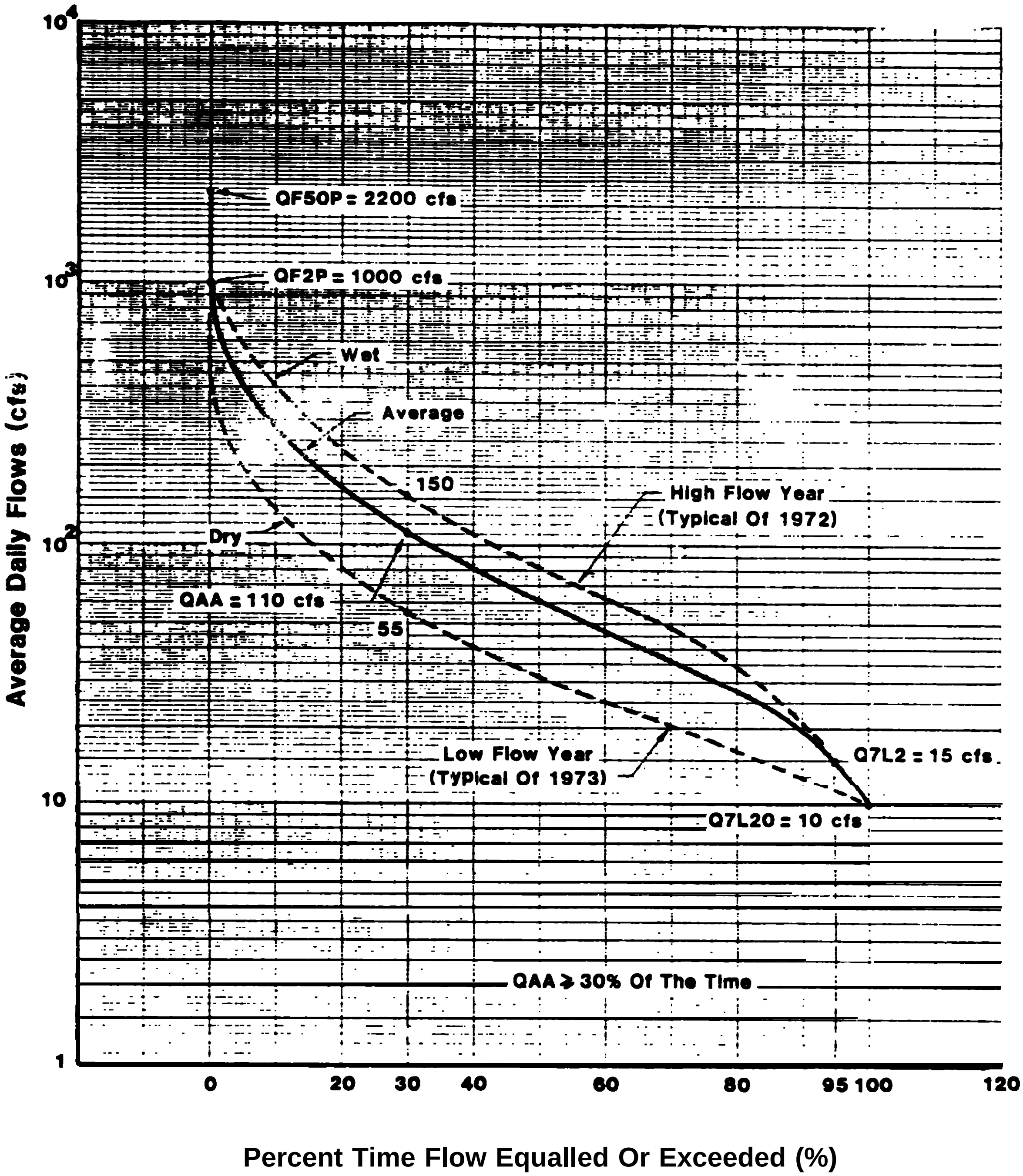

Figure 13. Crooked River Estimated Duration Curves at Project Site.

average annual flow (QAA) is equalled or exceeded 30 percent of the time, the Z-year low flow (Q7L2) is equalled or exceeded 95 percent of the time, and the 20-year low flow (Q7L20) is equalled or exceeded close to 100 percent of the time. Variability of this curve is estimated using a wet year like 1972 and a dry year like 1973. The variability in average annual flows for these two years is used as a guideline to estimate the typical average daily flows for a wet year and a dry year.

VII. HYDRAULIC DESIGN OF MEANDER CHANNELS

INTRODUCTION

There are two basic requirements for the design of the "pilot meanders" which must be considered simultaneously:

1. the hydraulic characteristics to develop a stable channel; and
2. the biological or habitat characteristics of the channel which are dependent on the channel geometry and its flow characteristics.

The habitat criteria[1] will be integrated into the meander design in the next chapter.

Initially, the meanders will be designed to fit natural criteria developed from data on other streams in the vicinity. Then these design criteria will be fit to the site conditions, and then adjusted to meet constraints such as minimizing excavation.

DESIGN CONSIDERATIONS

In attempting to restore these pilot reaches of Crooked River to a "more natural" state than currently exists, consideration of channel geometry must be included in three dimensions (or planes):

1. VERTICAL--plan view of the channel pattern (straight, braided or meandering);
2. PROFILE--the slope (or gradient) of the stream is related to the plan view, in that the stream slope controls velocity, and thus STREAM POWER, the bed material size distribution, and sediment transport; and
3. CROSS-SECTION--the "hydraulic geometry" of the channel relates water surface (top) width, mean flow depth and mean velocity to streamflow at various stages.

As the meander design progressed some constraints which had to be considered included:

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[1] Provided by D. Hair, U.S.Forest Service, July 20, 1984; are listed and discussed later.

1. fitting the meander channels to the existing "ponds" to help reduce the amount of excavation;
2. considering possible seepage losses out of the channel;
3. balancing the number and types of habitat features which should be designed into the meander construction, versus those which should be allowed to develop over time; and
4. location of the airstrip.

These constraints are addressed as they arise in the design process.

Design Geometry

Plan View

The meander pattern, valley length and stream length are the three major physical features to be considered in this view.

The meander pattern as it now exists in Crooked River in the project reach is as shown in Figs. 14A and 14C. Also shown in Figs. 14A and 14B is the meander pattern for a reach of Tenmile Creek of the same valley length of about 2.7 miles (this is not the Crooked River project length, but a comparative valley length). The drop in elevation over the 2.7 ±miles is 200 ft. in both valleys. The following table summarizes the plan view and gradients of the two streams.

Stream	Valley Length	Stream Length	Drop in Elevation	LS/LV	Stream Gradient	
Crooked	2.73	2.88	200	1.05	0.0132	(1.3%)
Tenmile	2.73	3.64	200	1.33	0.0104	(1.0%)
(Units)	(mi)	(mi)	(ft)	(-)	(-)	(%)
Symbol	LV	LS	D E	Sinuosity (P)	D E/LS	S

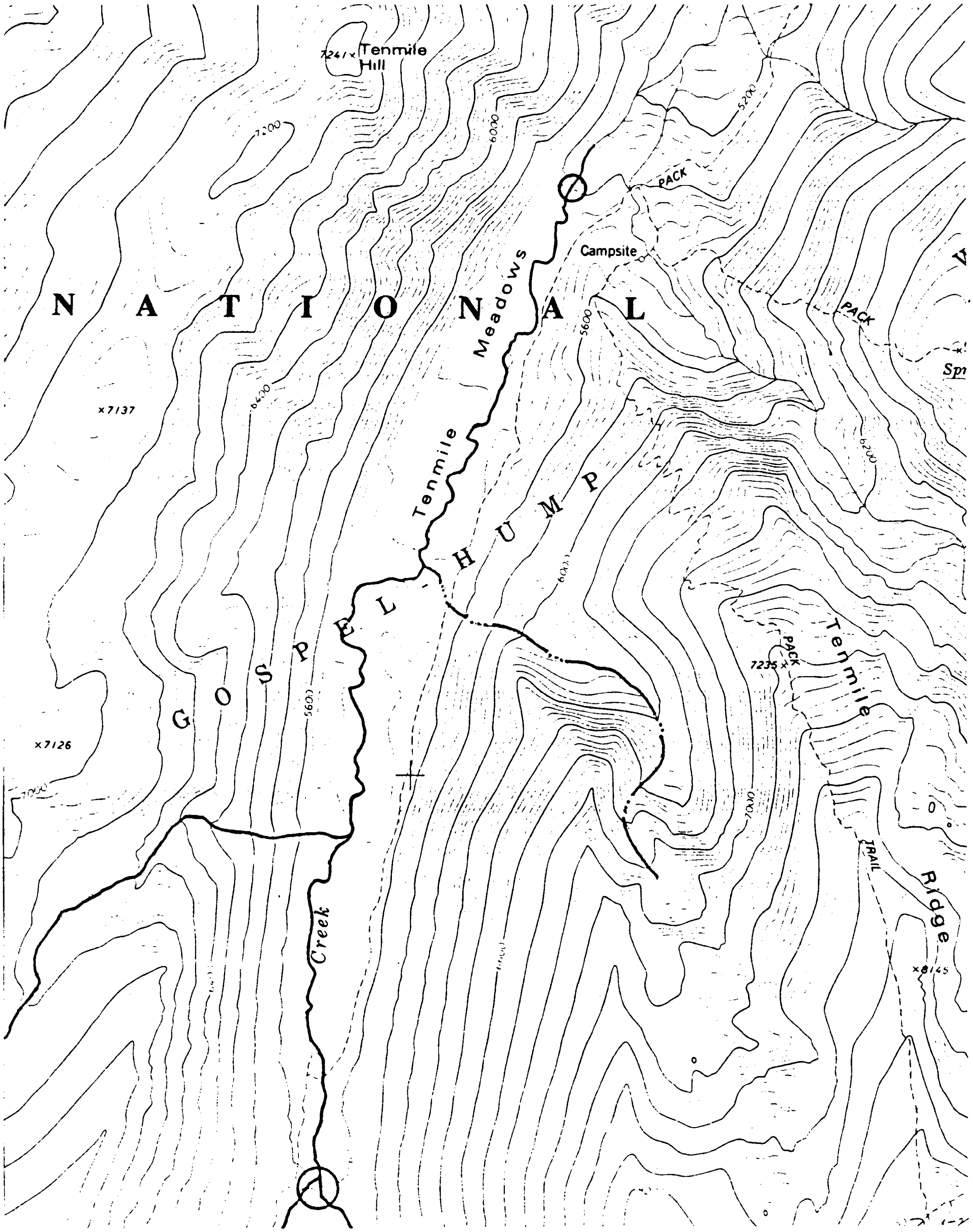

Fig. 14B. Map of Reach of Tenmile Creek Southwest of Crooked River Project Sit:: Used to Develop Natural Meander and Slope Criteria. USGS North Pole Quadrangle, 1979. Scale--1:24000.

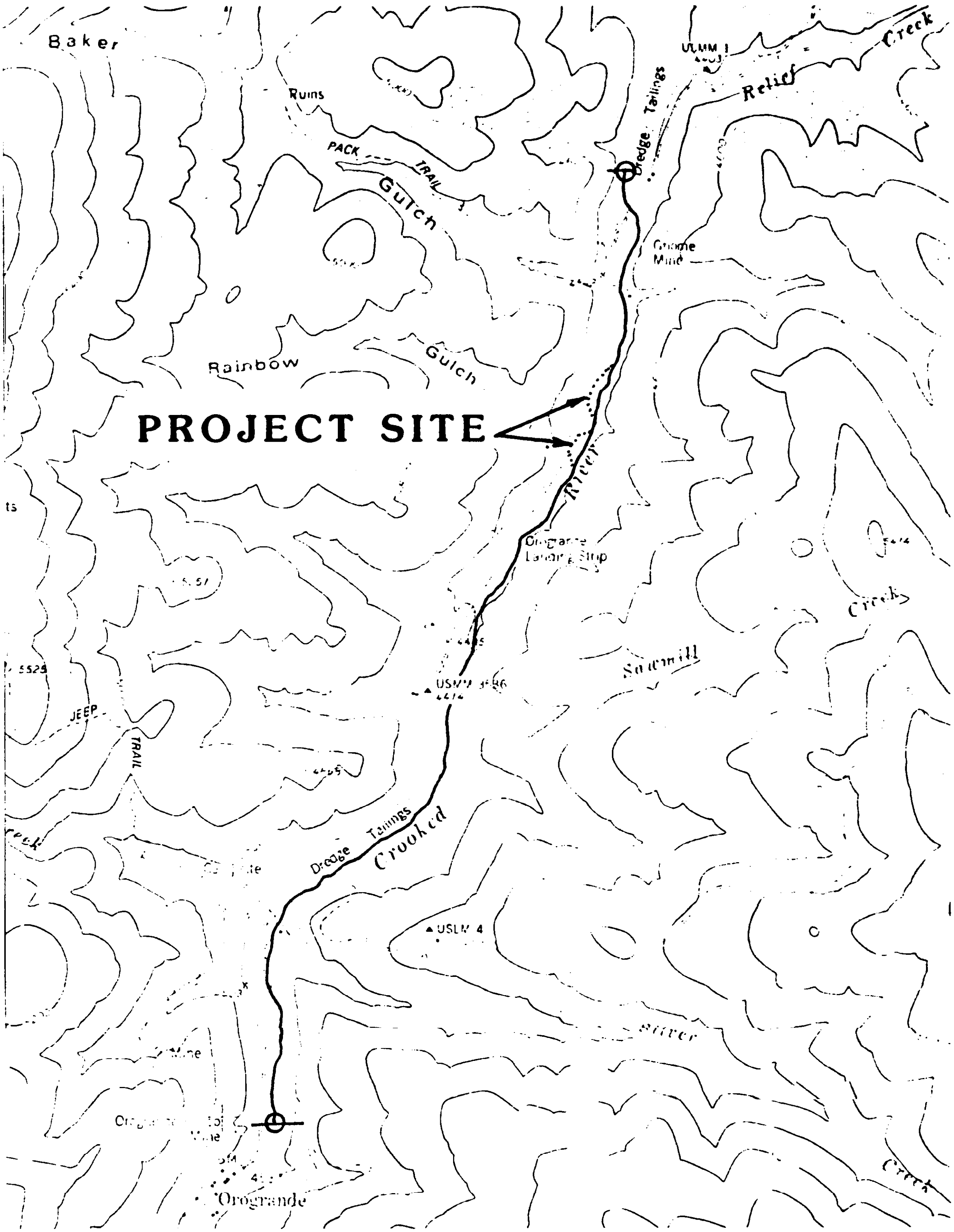

Fig. 14C. Map of Reach of Crooked River in Vicinity of Meander Restoration Project Site. From USGS Orogrande Quadrangle, 1979. Scale- 1:24000.

The valley gradients are the same (200 ft. in 2.73 mi.; 0.0138 or 1.4%). Although the Tenmile Creek valley is about twice as wide as the Crooked River project valley, the meander pattern maintains a relatively narrow band as shown in Figs. 14A and 14B. The meander pattern is classified as "irregular" which indicates that the pattern is controlled predominantly by the variable consistency of the deposits through which it flows. For example, the heterogeneous mixture of valley deposits presents the stream with varying resistances to scour and erosion, such as lenses of clay, partially cemented layers and deposits of larger bed materials from side valleys.

The local slope of the existing Crooked River project channel varies between 1.3 and 1.5 % which closely approximates the average valley slope. The sinuosity of the existing channel (LS/LV = P), P = 1.05 but should be closer to 1.33 as it is for Tenmile Creek in the table. This ratio will be one of the guides in designing the "pilot meanders."

Profile

The slope of Tenmile Creek, used as a natural reference, averages 1%, but of course local variations are steeper and flatter in bends and straight reaches, depending on local controls.

The slope of Crooked River in the vicinity of the project is an average of about 1.4%, but this has been altered somewhat by the installation of habitat improvement structures.

In designing the two meander "pilot channels" the average design slope will be about 1%, but local slopes in various parts of the new channels will vary between about 0.5 and 2%. These will be the average slopes between control point elevations.

Cross-Section

There are three basic alternative approaches which can be taken when designing the meander channel(s) in terms of the relationships among width, depth, velocity and stream flow, or as these features are collectively called, the "hydraulic geometry."

The approaches are:

1. Match the geometry with natural reaches of Crooked River or nearby "similar streams";

2. Develop "regional relationships" among channel characteristics, design flows and basin characteristics; and
3. Use hydraulic analysis of water surface profiles, shear stress on the boundaries, and bed material sizes related to that shear stress, with all of these related to a design flow.

The first method could not be used because no reach of Crooked River with similar valley slope and materials could be found in an undisturbed state. Tenmile Creek was too remote to acquire onsite transect data.

But, a U.S. Geological Survey report by Harenberg, et al. in 1980 gave detailed information on the hydraulic geometry of numerous gaging stations in the region. Also, a paper by Jackson and Van Haveren (1984), provided guidance on channel geometries which assist in the re-establishment of riparian vegetation and other considerations such as structures to provide stability in the channel banks until vegetation can be established.

Therefore the design process involved four major steps:

1. preliminary design of a channel 30 ft. wide at the bottom with 1:1 side slopes as exist in the dredge spoils with a uniform 1% bed slope;
2. development of regional channel design characteristics using bankfull flow (assumed to be a 2-year flood) for design;
3. comparing, verifying and adjusting the first two designs to fit with channel sections having flood plains for flows greater than the 2-year flood; and
4. fine-tuning the design to fit the project site constraints such as:
   (a) the existing contours;
   (b) the existing swales and ponds;
   (c) the elevation of the new meander channels with respect to the road; and
   (d) the location of the north end of the airstrip.

Meander Hydraulic Geometry

The design flows used to calculate depths, water surface profiles and shear stress in channels of various geometric cross-sections were:

Fifty-year flood:	QF50 = 2000 cfs
Two-year flood:	QF2 = 1000 cfs
Average Annual Flow:	QAA = 110 cfs
7-day, 2-yr., and	Q7L2 = 15 cfs
20-yr. Low Flows:	Q7L20 = 10 cfs

These flows were determined by the methods described in the section on HYDROLOGIC ANALYSIS.

Comparing the ratio of 50-year to two (2)-year floods for other gaging stations in the vicinity, it appears that the 2-year flood may be on the , order of only 800 cfs, rather than 1000 cfs. This assumes that the 50-year flood of 2000 cfs is approximately correct, as verified in the hydrologic regional analysis.

These design floods were used in the hydraulic design of the two new pilot meanders:

1. PRELIMINARY DESIGN

Bottom width (B) = 30 ft., 24 ft.; side slopes 1:1 and 1:2, no flood plain; calculate normal mean depths and critical[2] depths for:

(a) uniform bed slope; and

(b) various bed slopes to give desired bed material sizes and habitat conditions.

The normal and mean depth were calculated for flows of 2000, 1000 and 100 cfs. Low flows will follow the thalweg which will not cover the full width of the channel. The results of the preliminary analysis are summarized in Table 9.

A sketch of channel cross-sectional geometry, related to bottom widths and side slopes, and a nomenclature sketch, are presented in Figure 15.

2. DESIGN USING REGIONAL CHANNEL CHARACTERISTICS AND BANKFULL FLOW

Using data from Harenberg et al. (1980) the information on seven gaging stations, covering a range in drainage basin sizes which bracketed Crooked River (42 sq. mi.) at the meander site, has been summarized in Table 10. The relationships between: Bankfull flow,

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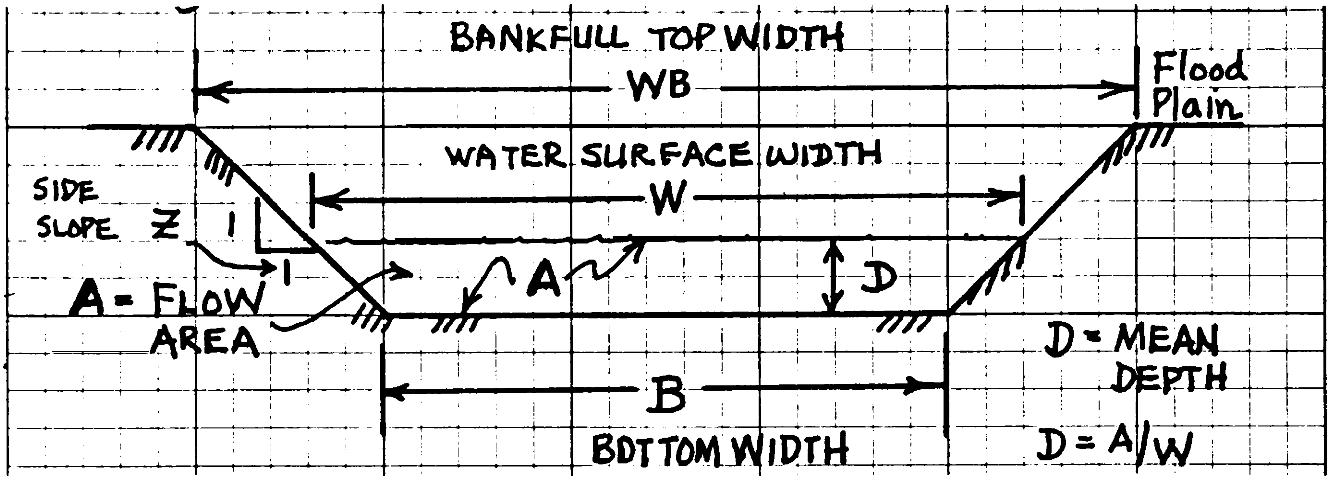
2 Transition depth between mild slopes (glide, pool) and steeper slopes (in riffles).

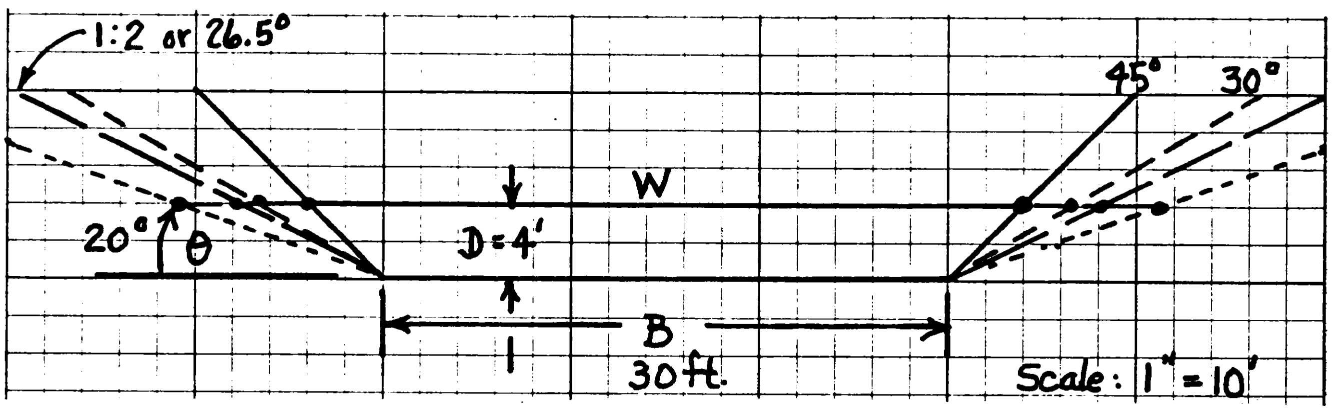
Table 9. Preliminary Analysis of Crooked River Meander Channel Geometry and Depth Related to Bed Slope, Side Slopes and Discharge.*

Flow Q (cfs)	Bottom Width B (ft)	Side Slope Z (-)	Bed Slope S (-)	Roughness Factor n (-)	Normal Depth y_n (ft)	Critical Depth y_c (ft)
2000	24	1:1	0.015	0.036	5.92	5.54
		1:2			5.44	5.16
	30	1:1			5.23	4.89
		1:2			4.91	4.64
1000	24	1:1			3.95	3.59
		1:2			3.72	3.42
	30	1:1			3.46	3.14
		1:2			3.32	3.04
100	24	1:1		0.040	1.06	0.81
		1:2			1.05	0.80
	30	1:1			0.93	0.70
		1:2			0.92	0.70
2000	30	1:1	0.015	0.036	4.63	4.89
			0.010		5.30	
			0.007		5.89	
			0.005		6.50	
1000	30	1:1	0.015	0.036	3.11	3.14
			0.010		3.51	
			0.005		4.32	
100	30	1:1	0.015	0.040	0.84	0.70
			0.010		0.94	
			0.005		1.16	

*See Fig. 15A for nomenclature. Calculated values using Manning's equation for assumed "n" values based on Barnes (1967) and field observation.



A. Nomenclature for Channel Geometry



B. Cross-Sectional Area and Side Slope
For B = 30 ft. and D= 4 ft.

B (ft.)	q °	w (ft.)	(B + W)/2	Area (Sq. ft.)	Ratio A q /A45
30	20	52	41	164	1.20
	26.5	46	38	152	1.12
	30	44	37	148	1.08
	45	38	34	136	1.00

Fig. 15. Channel Nomenclature and Flow Areas.

Table 10. Gaging Stations and Channel Characteristics Used in Regional Design Analysis*

Station No.	Station Name	Drainage Area (sq. mi.)	Bankfull Flow, QB (cfs)	Average Precipitation (in./yr.)	Average Annual Flow, QA (cfs)	BANKFULL CHANNEL GEOMETRY Top Width WB (ft)	Flow Area AB (sq. ft)	Mean Depth DB (ft)
12411000	Coeur d'Alene R.nr. Shoshone	335	5460	52	725	171	855	5.0
12413140	Placer Cr. nr. Wallace	15	330	52	39	44	67	1.5
12414900	St. Maries R. nr. Santa	275	2440	42	361	120	532	4.4
13336100	Meadow Cr. nr. Lowell	241	4400	45	437	111	454	4.1
13336850	Weir Cr. nr. Powell RS	13	137	--	--	31	34	1.2
13339700	Canal Gulch Cr. nr. Pierce RS	6	46	--	--	16	19	1.0
13341400	E.F. Potlatch R. nr. Bovill	42	496	46	60	40	92	2.3

*Station data from Harenberg et al. (1980).

QB (the 2-yr. flood, QF2 = 1000 cfs at the Crooked River project); Flow Area, AB, at bankfull flow; and Top Width, WB, at bankfull flow are related to drainage basin area (DA) in Figure 16.

Design equations developed from Figure 16 are:

Bankfull Flow:	$QB = 28.0\ (DA)^{0.90}$
Bankfull Area:	$AB = 6.0\ (DA)^{0.82}$
Bankfull Top:	$WB_1 = 14.0\ (DA)^{0.37}$ (Upper)
Width (Range of Values)	$WB_2 = 6.6\ (DA)^{0.50}$ (Lower)

An analysis of the Upper Salmon River channels by Emmett (1975) yielded the following similar equations: (averages)

$QB = 28.3\ (DA)^{0.69}$ UPPER SALMON
$AB = 5.6\ (DA)^{0.65}$ RIVER EQUATIONS
$WB = 8.1\ (DA)^{0.38}$; and a mean depth equation of
$DB = 0.69\ (DA)^{0.27}$.

Referring to Figure 17 the regional equation for depth at bankfull is
DB = 0.50 (DA) O-39.
These equations predict DB = 1.9 and 2.1 ft., respectively, at the project site. Average annual flow (QA and QAA)3 is shown in Figure 17 also.

Using the Crooked River Project drainage area of 42 square miles yields the following design features from Figures 16 and 17:

Bankfull Flow:	QB = 810 cfs
Bankfull Area:	AB = 129 sq. ft.
Top Width (Range):	WB = 42-56 ft.
Mean Depth:	DB = 2.2 ft.
Average Flow:	QA = 107 cfs; Confirms 110 used in Hydrologic Analysis for P = 50 in/yr ±.

To check these design values, data from Harenberg et al. (1980) was plotted from Table 10 relating the channel top width (WB), mean depth (DB), and flow area (AB) to bankfull flow (QB) as shown in Figure 18.

3 QA is used to concur with USGS nomenclature, and is the same average annual flow (QAA) in the HYDROLOGIC ANALYSIS Chapter.

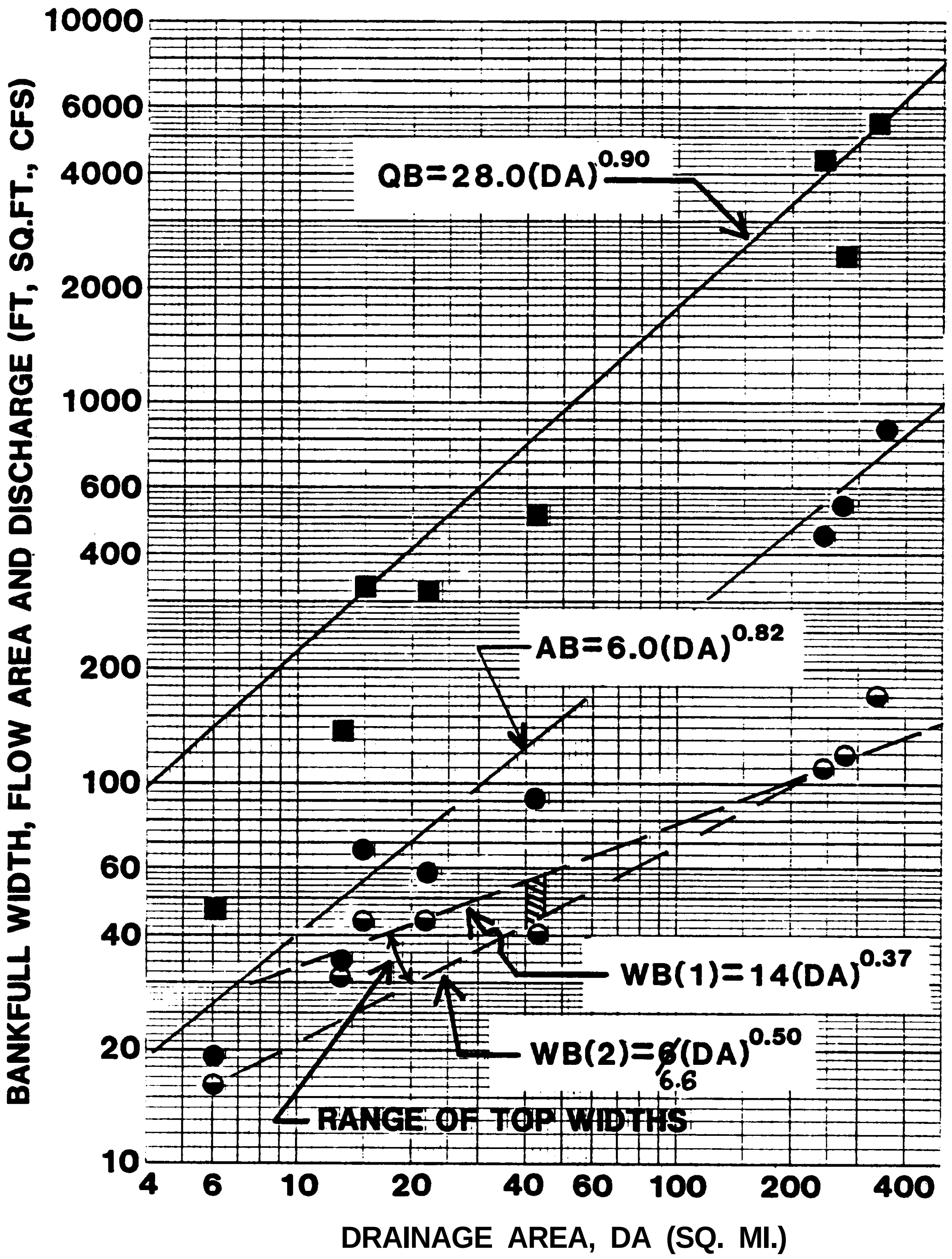


Fig. 16. Regional Analysis of Bankfull Flow (QB), Flow Area (AB), and Top Width (WB) Related to Basin Drainage Area (DA).

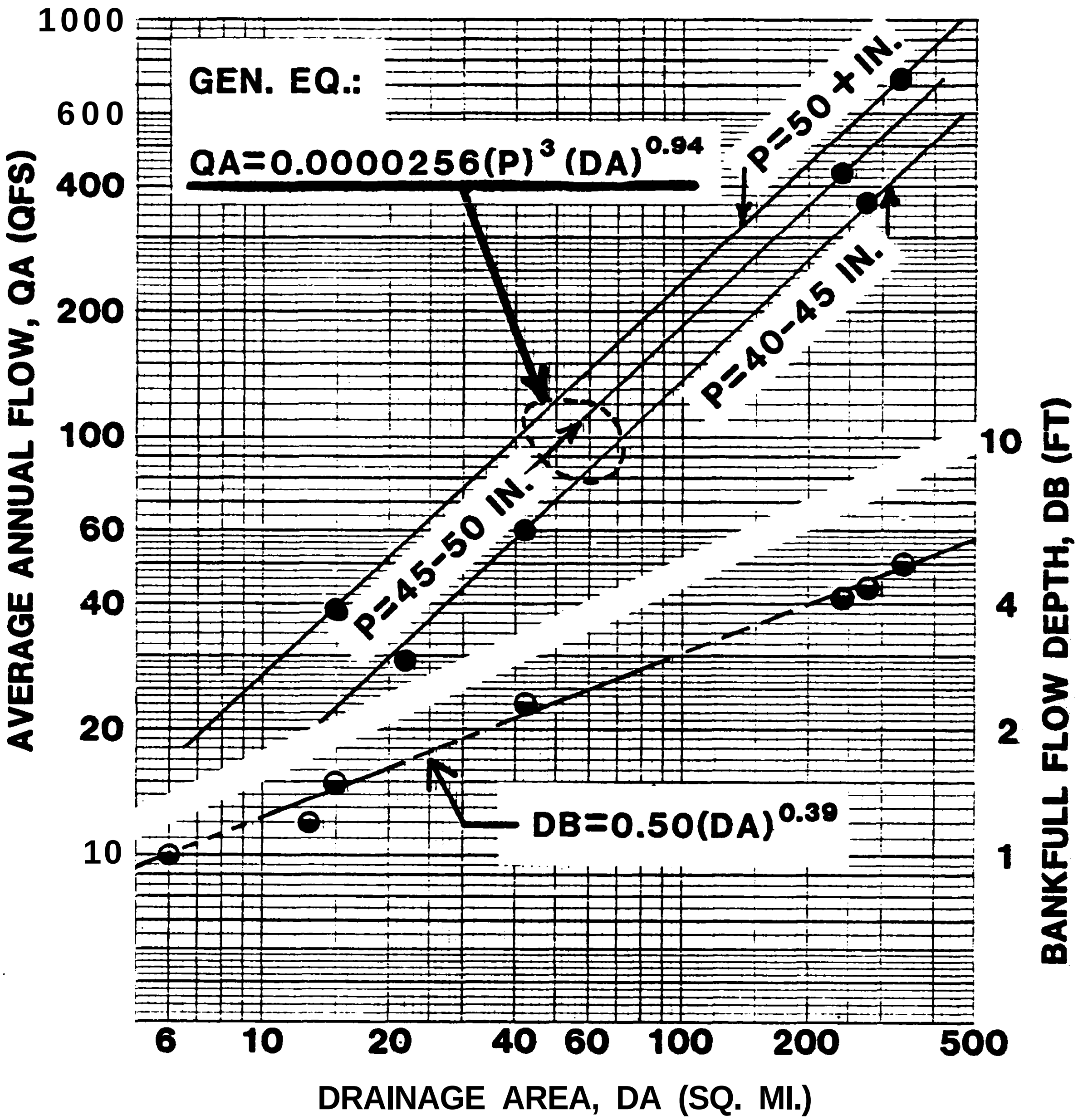


Fig. 17. Average Annual Flow and Bankfull Depth Related to Basin Drainage Area in Study Region.

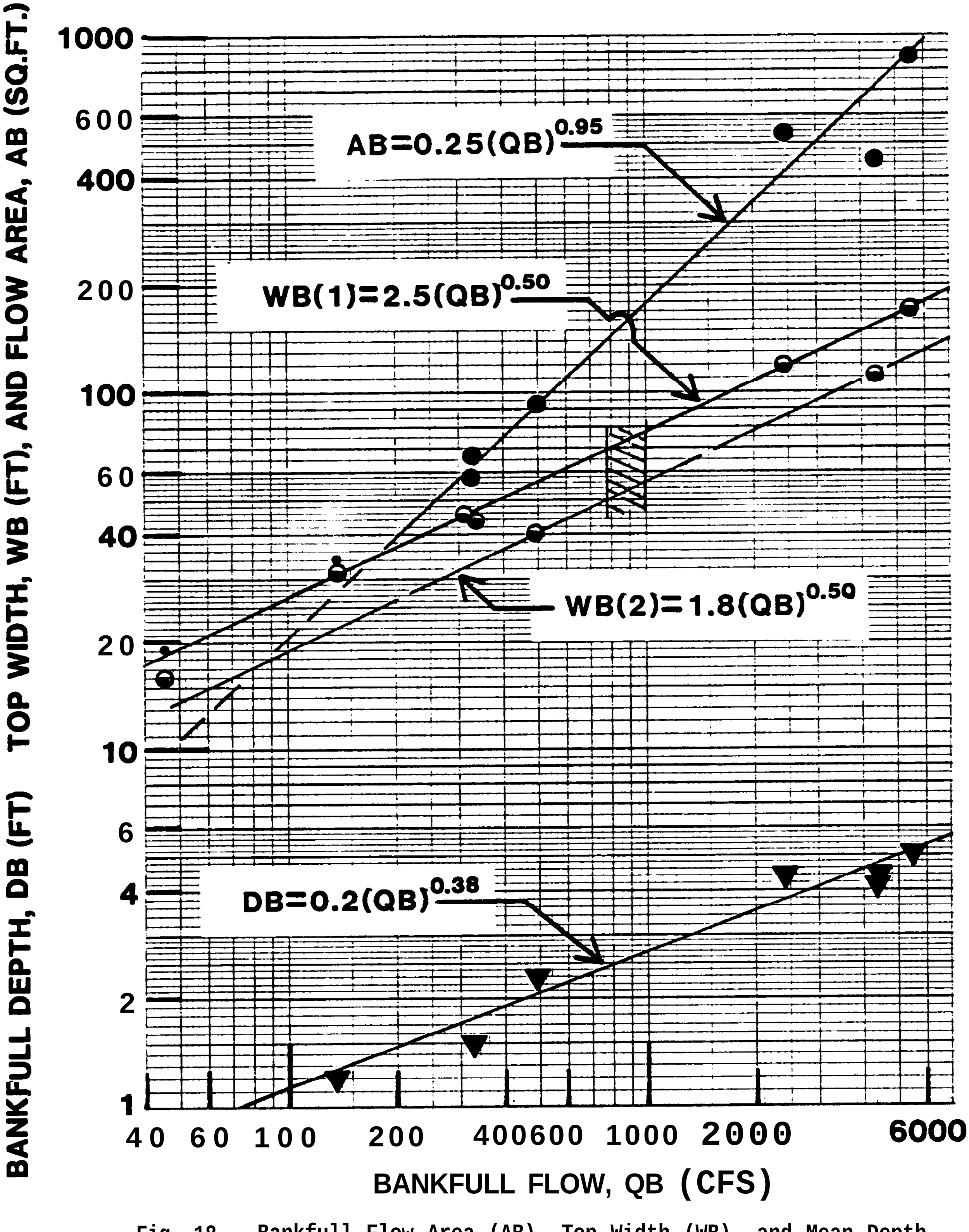


Fig. 18. Bankfull Flow Area (AB), Top Width (WB), and Mean Depth (DB), Related to Bankfull Flow (QB) in Study Region.

The equations resulting from this analysis are:

Flow Area: $AB = 0.25\ (QB)^{0.95}$
Top Width: $WB_1 = 2.5\ (QB)^{0.50}$
(Range) $WB_2 = 1.8\ (QB)^{0.50}$; and
Mean Depth: $DB = 0.3\ (QB)^{0.38}$.

These equations, using a range of bankfull flows of 800-1000 cfs, yield the following channel sizes for a bottom width of 40 ft. and 2H:1V side slopes:

Bankfull Flow, QB (cfs)	Bankfull Area, AB (Sq. ft.)	Top Widths WB_1 (ft.)	WB_2	Mean Depth DB (ft)
800	143	71	51	2.5
1000	179	79	57	2.8

The most consistent values for channel geometry and bankfull flow, based on the regional data, are:

Bankfull Flow: QB = 900 cfs
Bankfull Area: AB = 150 sq. ft.
Bankfull Top Width: WB = 55 ft.
Bankfull Depth: DB = 2.5 ft.

Based on the continuity equation (QB = AB x VB), VB = 900/150 = 6.0 fps is the mean velocity.

Using the table at the bottom of Figure 15, for a side slope of 45°, and DB = 2.5 ft, AB = only 81 sq. ft. (q = 20°, AB = 92 sq. ft.).

Therefore, the bed width B will need to be increased to about 36 ft (B). Then, for q = 20° to enhance vegetative growth, and DB = 2.5 ft., WB = 50 ft.

If DB = 3.0 ft (controlled by channel slope), then for q = 20°, B = 40 ft.; WB = 56.4 ft. and AB =.145 sq. ft. and VB = 900/145 = 6.2 fps.

The depths, calculated for 1000 cfs for various slopes and recorded in Table 9, showed Y_N[4] = 3.3 ft. and YC = 3.0 ft. for B = 30 ft. For B = 40 ft., YN = 2.4 ft at 1000 cfs.

If DB = 3.0 ft., for a side slope of 2H:1V, B = 40 ft., WB = 52.0 ft., AB = 138 sq. ft. and VB = 6.5 fps. If QB = 800 cfs, VB = 5.8 fps, about 11% less than at 900 cfs. It would probably be best to make the bank height only 2.0 ft. (DB) so that the flow would spread onto the flood plain more frequently, and accelerate habitat development. Also, the base width of the channel (B) could possibly be reduced to say 35 ft. which also would encourage more frequent flood plain flow. For these two base width (B) conditions of 35 and 40 ft., bankfull flow (as a function of slope), would be about as shown in Table 11, for a roughness coefficient (n) of 0.036 in Manning's equation and side slopes of 2H:1V.

Table 11. Bankfull Flow Related to Channel Bottom Width and Slope for 2:1 Side Slopes and Bankfull Depth of Two Feet

Bottom Width, (B), ft.	Bed Slope, (S) ft.	Bankfull Flow, (QB), cfs.
35	0.005	333
	0.010	470
	0.015	577
	0.020	666
40	0.005	370
	0.010	524
	0.015	640
	0.020	740

[4] YN and YC are normal and critical depths in the trapezoidal channel with a 40-ft. wide base (B) and 1:2 side slopes.

It appears that narrowing the channel to 35 ft. at the base might cause too frequent overtopping of the banks, and/or channel widening due to higher velocities. Therefore, it appears to be best to hold the bottom width (B) at 40 ft. and reduce the flood plain (bankfull depth, DB) to 2.0 ft. ± above the meander channel bed.

Depending on the channel slope, normal depth will be greater or less than critical depth, providing either pools or riffles, respectively. The design profiles, velocities, sizes of bed materials, and channel geometry are discussed in the next sections.

Comparison of Channel Size With Other Empirical Methods

Based on the work done elsewhere in other gravel-cobble streams, the estimated size of the bankfull channel, derived from the regional analysis, was compared with extra-regional equations. Kellerhals (1967) developed a series of equations for the geometry of straight reaches of gravel-paved stream beds in metric units:

A. Channel Top Width: $W = 3.26\,(Q)^{0.5}$

B. Velocity, Shear Stress, Depth and Grain Size: $\dfrac{V}{\sqrt{gRS}} = 6.5\left(\dfrac{d}{D90}\right)^{0.25}$

C. Critical Shear Stress: $\tau_{oc} = \rho_w gRs = 15.79\,(D90)^{0.80}$

D. Mean Depth: $d = 0.183\,(Q)^{0.4}\,(D90)^{-0.12}$

E. Mean Velocity: $V = 1.68\,(Q)^{0.1}\,(D90)^{0.12}$

F. Channel Slope: $S = 0.086\,(Q)^{-0.4}\,(D90)^{0.92}$

Using Eqs. A, D, E, and F, the top width, (W), mean depth, (D), mean velocity (V) and Slope (S) for normal depth were calculated for the average annual flow of 100 cfs, and flood flows of 1000 and 2000 cfs, as shown in Table 12.

Table 12. Channel Geometry Estimation for Crooked River Based on Gravel Stream Equations from Kellerhals (1967)

Equation	For	Discharges, cfs 100	1000	2000
A	W (m)	5.5	17.4	24.6
	(ft)	18.0	57.0	81.0
D	D (m)	0.33	0.84	1.11
	(ft)	1.10	2.80	3.60
E	V (mps)	1.6	2.0	2.1
	(fps)	5.1	6.5	7.0
F	s (-)	0.015	0.005	0.004

These channel characteristics, when calculated using the regional analysis of channel parameters, gave (for Q = QBF = 1000 cfs), WB = 52.0 ft., DB = 3.0 ft., and VB = 6.5 fps, very close to the values in the fourth column in Table 12.

Estimated Bed Material Sizes Related to Channel Slope

Using information on the relationships between mean grain diameter (D50) and channel slope (S) from Jackson and Van Haveren (1984, Table 1, and Fig. 4, pages 698, 699), an equation was developed such that

$$D50 = 4054\ (S)^{1.13}.$$

The data for this equation were taken in a stable reach of Badger Creek, Colorado for which the authors were trying to reconstruct a disturbed meadow. The graphical relationship for this equation is shown on the left side of Fig. 19. In addition, the stream power was calculated from the

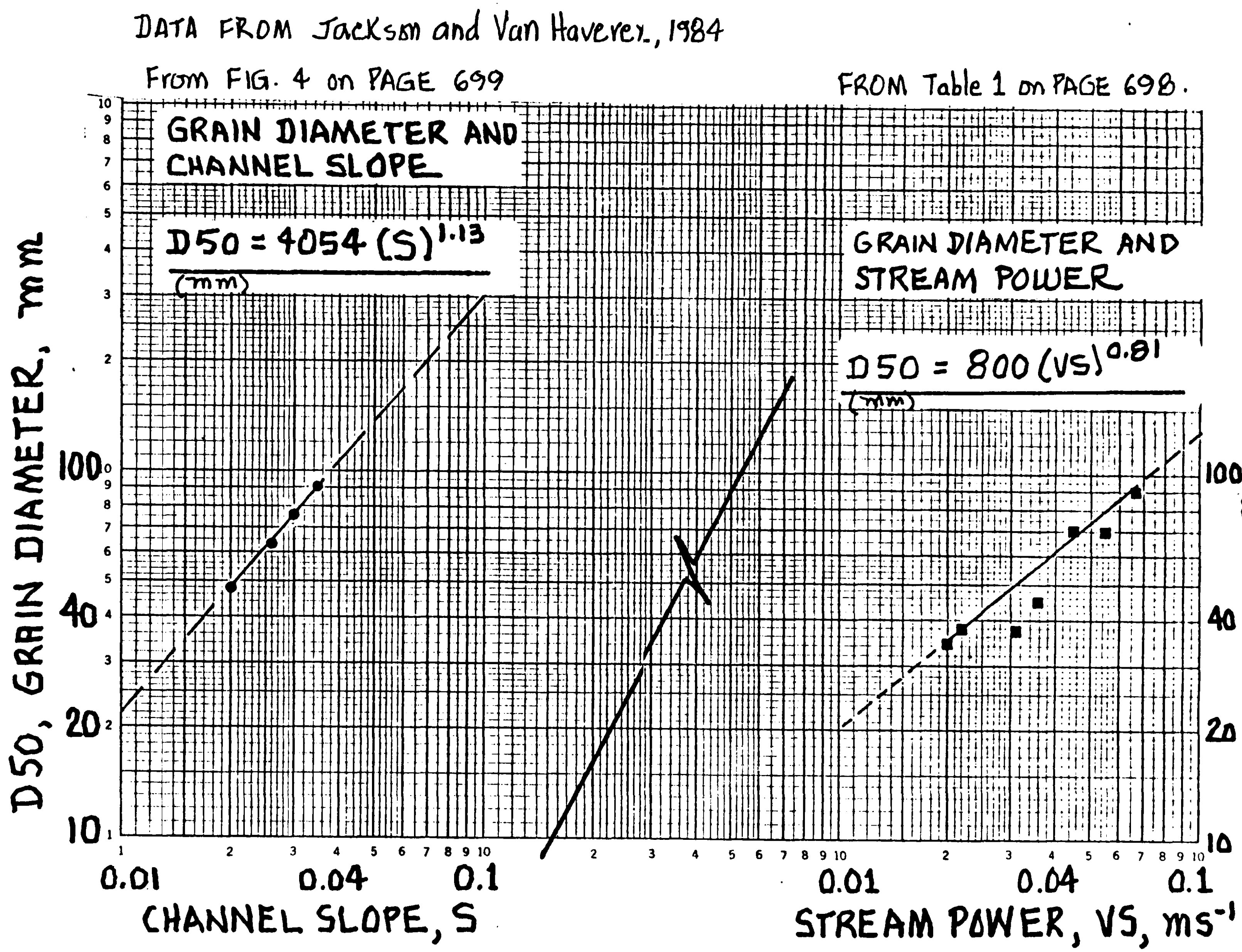


Fig. 19. Mean Grain Diameter, D50, Related to Channel Slope, S, and Stream Power, VS.

Badger Creek data and plotted versus D50 on the right side of Fig. 19 yielding the equation

$$D50 = 800\ (VS)^{0.81}$$

where V = the mean velocity at bankfull flow in m/s, S is the slope and D50 is the mean grain diameter in mm.

Applying these equations to crooked River under the design conditions of bankfull flow (QB = 1000 cfs, VB = 6.5 fps) the anticipated mean grain size on the bed can be related to the design slopes as shown in Table 13.

Table 13. Estimated Mean Grain Diameter on Streambed (050) Related to Stream and Stream Power at Bankfull Flow

Bed Slope, S	Bankfull Flow, QB, cfs*	Mean Velocity, V: ft/sec	Mean Velocity, V: m/s	Stream Power, VS, m/s	Estimated D50, mm**: From Slope	Estimated D50, mm**: From Stream Power
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.005	300	3.4	1.05	0.005	10.1 (0.40)	11.1 (0.44)
0.010	425	4.8	1.46	0.015	22.3 (0.88)	26.6 (1.05)
0.015	520	5.9	1.80	0.027	34.8 (1.37)	42.9 (1.69)
0.020	600	6.8	2.10	0.042	49.2 (1.94)	61.4 (2.42)

*Flows from Table 11, but reduced by 20% to account for n = 0.045 (see text).
**Values in ( ) are in inches.

The agreement between the values in columns (6) and (7) is quite good. Referring to Fig. 19, note that the left graph is for average values (Col. 6), whereas the right graph is drawn through the upper data points (Col. 7). Also, the right graph for stream power (Col. 7, VS) uses velocities estimated from Manning's equation using the roughness factor n = 0.045. Therefore, the grain diameters in column (7) were estimated using n = 0.045, the channel bed width (B)= 40 ft, and the bankfull depth, DB = 2.0 ft. If n = 0.036, as was estimated for the Crooked River meanders, the values calculated for D50 in column (7) would decrease by about 20%.As n decreases, velocity increases, and D50 would decrease by about $(0.045/0.036)^{0.81} = 1.20$, or 20% smaller in the calibration graph.

Had n = 0.036 been used in the original calibration data from Badger Creek, the right graph in Fig.19 would have been shifted to the right, thus predicting smaller D50 values,by about 20%, for the same stream power.

So, in the Crooked River case using n = 0.036, we should have D50 values about 20% larger than those using the graphs and equations in Figure 19.

Size distributions were not run on the Crooked River bed materials, but depending on the parent material and slope, the sizes would range about as shown below

		Sizes	
Slopes	D16	D50	D84 (inches)
0.005	(-)	0.50	(-)
0.010	0.30-0.40	1.00	4.0-5.0
0.915	0.50-0.60	1.50	6.0-7.5
0.020	0.75-0.90	2.25	8.0-24.0

MEANDER CHANNEL LAYOUT IN PLAN, PROFILE, AND TRANSECT

Introduction

Drawings A, B, and C, which depict the site plan, survey controls, cross-sections (transects) and meander layouts are located at the back of this report.

All of the site water bodies (the existing streams and the various ponds) are shown in Drawing C, which includes the original survey control and preliminary route lines for the two meanders. Water surface elevations taken during several of the site visits, are recorded in Drawing C to provide information on the stream profile. After the original survey controls were vandalized (except CP-7, CP-8, CP-10, and BM-3), the site had to be re-surveyed and the control system re-established.

This final survey was completed on October 19-20, 1984. This control system and the centerlines (P-lines) for the two meanders are shown in drawing A. To avoid a possible second destruction of the survey, all the control points (CPs) were spray painted with orange paint and buried under cairns. In addition, the CPs were tied in with measurements from blazed trees. Also, the P-lines were thoroughly cleared of trees so that the routes are obvious, and the stations (0+00, 0+50, etc.) were spray-painted orange on rocks every 50 ft. Notes describing the location and triangulation points of the final survey are in Appendix II of this report after the list of references.

Description of Meander Channels

The details of the two meander channel locations, curvatures, stations, bed elevations, transects and relations to existing ponds are presented in Drawing C. After it was considered at the meeting on February 13, 1985, not to construct the meanders, the transects for the downstream meander were not laid out in Drawing C. Also, there was not time on October 19-20 to re-survey and stake the transects in the downstream meander. This will have to be done if the meander is to be built. But, the cross-sections for the upstream meander (No. 1) which are shown in Drawing B are typical of transects throughout the meanders.

Meander Plan View

As described in previous sections on the hydraulic geometry of the channel, the natural meander patterns in these valley systems are "irregular." This indicates that they are relatively unstable, and the meanders translate laterally and downstream as "softer spots" are eroded more rapidly than other parts of the banks. In order to stabilize the new meanders more rapidly, so that the riparian zone would re-establish more quickly, these meanders were designed with a uniform, long radius of curvature.

$$RC = 2.5\ (WB)$$

where RC is the center radius of curvature, which in natural channels averages about 2.5 times the width of the channel at bankfull flow. For our original channel, flowing 3 ft. deep (DB) at bankfull, with 2H:1V side slopes, and 40 ft. wide at the base (B), the top width (WB) would be 52 ft. For the suggested revised channel with the lower flood plain (DB = 2 ft. instead of 3 ft.), the top width would be 48 ft. Therefore, a radius of curvature (RC) of 2.5 (50), or 125 ft., was used to blend the new meanders into the existing stream channel and to fit them into the ponds.

The plan views of the meanders are shown in drawing B along with the layouts on the stationed P-lines which were thoroughly cleared last October.

Meander Profiles

The bed elevations of the upstream meander are shown on the centerline of the transects in Drawing B. These elevations control the slope in each reach of the meanders.

The details of the profiles, including stations on the centerlines, ground elevations, meander (channel) bed elevations, center cut depth and notes on the channel slope and special features are listed in Table 14 and Table 15. Due to the shifting in routes between the preliminary (7/4/85) and final (10/20/85) surveys, the loss of some survey markers, and shortage of time, some of the ground elevations on the centerline had to be estimated. The various meander slopes govern the sizes of the bed material as discussed in the previous section (Table 13). All the changes in grade will have to be stabilized with logs set at the control elevations. These features are discussed in more detail under Habitat Improvement Features.

Meander Channel Transects and Capacity

The transects for the meander channels, as shown for the upstream meander in Drawing B, are based on a standard cross-section shown in the center of Figure 20. The bottom (B) is 40 ft. wide, side slopes are based on a relatively flat grade of two horizontal to one vertical and the flood plain height is 3 ft. in the center sketch. As was discussed earlier, the flood plain could be lowered one foot (DB = 2 ft) so that the plain would be inundated more frequently and encourage the establishment of riparian vegetation.

The next factor to consider is that if the bankfull depth of flow is set at DB = 2 or 3 ft., which portions of the channel on certain slopes (Tables 14 and 15) will overtop at a certain discharge. The left hand series of graphs (parallel lines) in Fig. 20 shows discharge (flow) related to depth (y = 1 to 5') and to slope (S = 0.005 to 0.020, or from 0.5 to 2%). The parallel lines indicate that for each depth (y) above the bed there is a general equation for flow such that

$$Q = C\ (S)^{0.5}.$$

This is just a condensed form of the Manning equation solved for the given channel shape at each depth from 1 to 5 ft. and for n = 0.036.

Table 14. Profile Along Upstream Restored Crooked River Meander Centerline*

Station on Centerline (ft)	Ground Elev. (ft)	Channel** Bed Elev. (ft)	cut Depth (ft)	Notes
-(1+00)	993.0	993.0	0.0	1.0% slope to Sta. 0+00
0+00	100.4	992.0	8.4	
0+50	999.2e	991.8	7.4	0.5% slope (0+00)-(1+00)
1+00	998.0e	991.5	6.5	1.5% slope for 100 ft
1+50	993.0e	990.8	2.2	Fill left side
2+00	992.3	990.0	2.3	2.0% slope for 100 ft
3+00	990.0	998.0	2.0	
3+50	Pond No. 1 bed elev. 984.0			
4+00	991.5	988.0	3.5	1% slope to end, Sta. 8+40
4+50	992.5	987.5	5.0	Fill left swale
5+00	988.2	987.0	1.2	
5+50	991.8	986.5	5.3	0.5 drop every 50 ft with notched sill logs
6+00	990.4	986.0	4.4	
6+50	988.3	985.5	2.8	
7+00	993.0	985.0	8.0	
7+50	984.9	984.5	0.4	
8+00	984.0	984.0	0.0	Rebuild habitat structures downstream to next meander. Return to stream just above Crib No. 1.

*Based on survey of 10/20/84 Refer to Drawings A and B at back of report for, locations.e, elevation estimated.

**Meander bed elevation.

Table 15. Profile Along Crooked River Downstream Restored Meander Centerline*

Station on Centerline (ft)	Ground Elev. (ft)	Channel** Bed Elev. (ft)	cut Depth (ft)	Notes
-(0+50)	978 .0	978 .0	0.0	Existing streambed
0+50	988.0e	977 .0	11.0	1% slope to sta. 1+90
0+90	987.0e	976.6	10.4	
1+90	983.0e	975.6	7.4	Slope 1.5% (1+90)-(2+90)
2+90	974.0	974.0	0.0	
2+90 to	4+90:	Pond No. 8		
4+90	976.0	974.9	1.1	1.4% slope, with 0.7 ft drop every 50 ft using notched log structures to Sta. 7+90.
5+40	979.3	974.2	5.1	
5+90	979.0e	973.5	5.5	
6+40	981.0e	972.8	8.2	
6+90	980.0e	972.1	7.9	
7+40	976.0	971.4	4.6	
7+90	971.4	970.7	0.7	
8+40	970.0	970.0	0.0	Return to existing stream just above Crib No. 5.

*Based on survey of 10/20/84. Refer to Drawings A and B at back of report for locations. e, elevation estimated.

**Meander bed elevation.

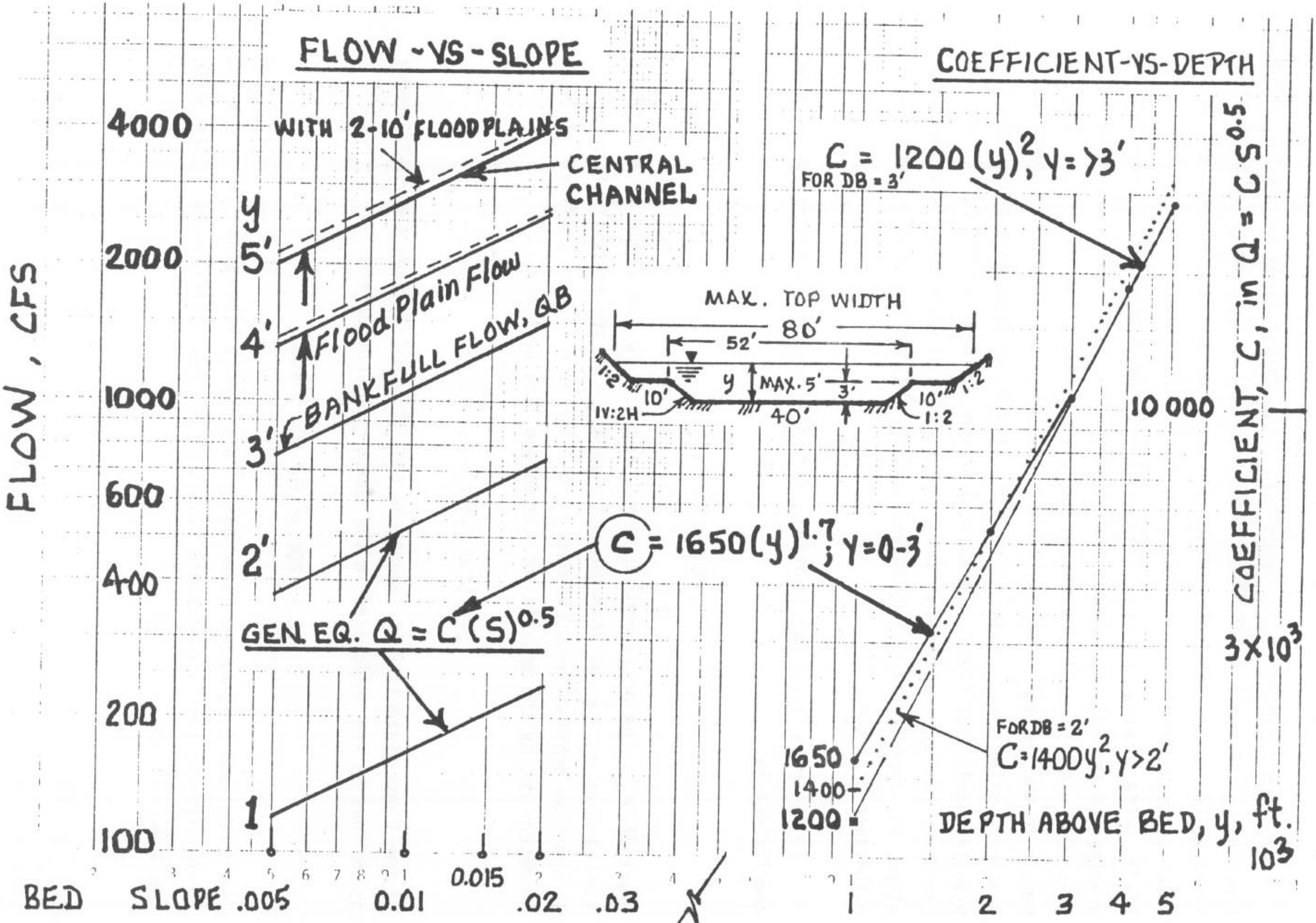


Fig. 20. Flow Capacity of Meander Channels Related to Channel Slope and Depths of Flow from 1.0 to 5.0 Feet.

When the depth of flow exceeds 3 ft., the dashed lines (above the solid lines for y = 4 and 5 ft) indicate the total flow including channel plus flood plain flow. The difference between the pairs of dashed and solid lines indicate the relatively small amount of flood plain flow on the two, 10-ft. wide plains, or one, 20-ft. plain. As the riparian vegetation develops on the 2:1 side slopes and flood plains, the flow resistance will increase. As a result, a larger portion of the flow will be forced to remain in the central channel, thus increasing the depth. Through this process, either at a natural rate of change, or accelerated by shoreline plantings and other steps, the natural stream meander will stabilize. To complete the general analysis of the relationships among flow, depth and slope, the coefficient (C) is solved for, on the right side of Figure 20, as a function of depth.

For depths less the bankfull (DB) = 2 or 3 ft), the value of the coefficient is

$$C = 1650\ (y)^{1.7}$$

where 1650 is the intercept at y = 1 and 1.7 is the slope of the graph (solid line with arrow from the above equation in the center of Figure 20). If the flow depth exceeds the bank height for DB = 2', the coefficient will be determined by the equation of the dotted line such that

$$C = 1400\ (y)^2 \text{ for } y > 2 \text{ ft.}$$

If the flood plain is 3 ft. above the bed (DB = 3 ft), then the coefficient is defined by the solid line in the upper right corner and

$$c = 1200\ y^2 \text{ for } y > 3 \text{ ft.}$$

The dotted and long-dashed lower graphs are merely extensions to y = 1 ft. to demonstrate the locations and values of the new coefficients (1200, 1400, and 1650).

By substituting the three equations for the coefficient (C) as a function of depth (y) into the general equation, a set of governing equations can be developed as presented in Table 16.

Table 16. Equations Relating Flow in Crooked River Meanders to Depth of Flow, Flood Plain Height, and Channel Slope

Range of Flow Depth, Y, ft.	Equation	Conditions
o-2	$Q = 1650\ (y)^{1.7}\ (S)^{0.5}$	Bankfull Depth, DB = 2 ft
>2-5	$Q = 1400\ (y)^{2}\ (S)^{0.5}$	-do-
o-3	$Q = 1650\ (y)^{1.7}\ (S)^{0.5}$	Bankfull Depth, DB = 3 ft
>3-5	$Q = 1200\ (y)^{2}\ (S)^{0.5}$	-do-

The relationships among discharge, depth, slope, and flood plain flow can be examined in the series of parallel lines on the left side of Figure 20, and some conclusions drawn regarding limiting slopes and discharges which affect channel design.

For a 2-ft. flood plain height, the flood plain will be overtopped for all slopes ranging from 0.5%-2.0% at discharges ranging from about 370-740 cfs. This means that almost every year the entire reach of flood plain (on all slopes) will be inundated.

If the flood plain is 3 ft. above the channel bed, then for channel reaches with slopes of 0.5%-1.0% (0.005 - 0.010 on bottom scale), it will overtop between 760-1100 cfs. The average annual peak flood was estimated to be about 1000 cfs. The peak flow is not as important for flood plain development as are the three-day and seven-day average high daily flows.

For streams in the vicinity of Crooked River (Lochsa, Selway, South Fork Clearwater, and North Fork Clearwater) several years of record showed that the average one-day high flow runs about 75-80% of the instantaneous peak flow in the South Fork basin. For all the basins there is a solid relationship between the seven-day average annual high flow and its related one-day high such that

$$Q7H = 0.08\ (Q1H)^{1.25}.$$

So, for a two-year peak flood of 1000 cfs (considered to be natural bankfull flow, QB), the one-day high would be about 750-800 cfs.

The seven-day average high flow would be about

$$Q7H = 0.08\ (800)^{1.25} = 340 \text{ cfs}.$$

The three-day high is related to the one-day high approximately by

$$Q3H = 0.18\ (Q1H)^{1.17}$$

or, for Q1H = 800 cfs,

$$Q3H = 450 \text{ cfs}.$$

This means that there is a 50% chance in any year that (referring to Figure 20, lower left two lines) for a 2-ft. flood plain bank height:

1. All parts of the floodplain with channel slopes from 0.005-0.020 will be overtopped by the one-day average high flow (Q1H) of 800 cfs;

2. The flatter slopes of 0.005-0.010 will be inundated for about three days (Q3H = 450 cfs); and

3. Only the flood plains on the channel reaches with a slope of 0.005 will be inundated for longer than three days (Q7H = 340 cfs).

So it appears that the decision to reduce the bankfull depth (flood plain height) from three to two feet is a positive step towards improving the generation on good riparian vegetation. Flows less than the average seven-day high flow will still reach the root zone and provide silt on the 2:1 side slopes.

An estimate can be made of the amount of flood plain area that will be inundated as a function of slope and discharge, by combining the information in Tables 14 and 15 on channel slope with the hydraulic geometry in Figure 20 and the relationships among one-, three-, and seven-day high flows. The results of this analysis are shown in Table 17.

Although the flood plains are planned to be only a total of about 20 feet wide, this width is controlled by the design objective of minimizing excavation costs, and if space is available they should be 20-30 ft. wide.

When the channels are flowing approximately five feet deep above the bed (2-3 ft above flood plain) the flattest (0.5%) channel will just be able to initially pass the 50-year peak flood of about 2000 cfs. When the flood plains are unvegetated the total flow capacity will be about 2200 cfs. To allow for future reduced flow capacity of the flood plain due to vegetation, as a general rule there should be at least two feet of freeboard on low embankments to contain the flows. Overtopping would not cause problems if the top of the bank was relatively flat for a long distance, such as west of Pond No. 1. But if the embankment had been constructed on fill, the outside slope should be graded at least 3H:1V to help avoid breaching.

Table 17. Flood Plain Area Inundated in Meanders as a Function of Channel Slope and Average Flood Flow.

Channel Slopes, S <0.005	0.010	0.015	0.020	Stations from Tables 14 and 15	Notes
Upstream Meander					
	100			-1+00 0+00	Entrance
100				0+00 1+00	
		100		1+00 2+00	
			100	2+00 3+00	Steep into Pond.
100				3+00 4+00	Pond No. 1 level.
	400			4+00 8+00	Log drops at 1% every 50 ft. (0.5 ft).
Downstream Meander					
	240			-0+50 1+90	Entrance.
		100		1+90 2+90	Approach to Pond No. 7.
200				2+90 4+90	Pond No. 7.
		350		4+90 8+40	Log drops at 1.40% every 50 ft. (0.7 ft).
Total Lengths for Each Slope					
400	740	550	100	1790 ft	
Total Area in Flood Plain*					
8000	14800	11000	2000	35,800 sq. ft	

Flood Plains Inundated for the Slopes and Discharges Shown

Areas				Discharges (cfs)
X	X	X	X	2000 (50-Year Flood)
X	X	X	X	1000 (2-Year Flood)
X	X	X	X	800 (Average Maximum Daily Flow)
X	X			500 (Q3H)
X				350 (Q7H)

*Two 10-ft wide flood plains, one each side of channel; or one 20-ft flood plain on one side. Flood plains can be wider, but this is all the width required to pass 2000 cfs if 2 ft. of freeboard are added for safety.

VIII. HABITAT FEATURES

Introduction

One of the most important habitat improvement features associated with the pilot meander(s) will be the inclusion of flood plains. These will, by being set lower than normal, be inundated more frequently and for longer periods of time.

A major consideration in the selection and design of habitat features for a restored (new, raw, inert) channel is the rate at which the decision-makers wish to have the channel return to a more "natural" state. The approach taken in this report will be to recommend a series of steps and features to accelerate the development of potential habitat volume and diversity. Then, the managers can decide which features will be installed initially, thus governing the potential rate of habitat development.

The installation, during channel construction, of an aggregate sorting and mixing plant is well worth considering. Then fines could be placed on flood plains, spawning gravels could be mixed and placed in certain reaches and riprap (largest available natural materials) could be stockpiled. The plant could be included in the call for bids as a separate item, and then be rejected or accepted as part of the award. This activity would certainly assist in the acceleration of habitat diversity.

A series of recommended habitat features is discussed, their typical design features are presented and their recommended locations are noted on sketches of the meanders.

General Classification of Habitat Features

Habitat features are considered to be any aspect of the meander design which assists fish' in spawning, incubation, rearing or migration, plus the installation of specific habitat improvement structures or augmenting features such as plantings.

There are three general categories of habitat features which can be considered for the meanders:

(1) Those which are ancillary parts of the hydraulic design of the channels (such as bed elevation control sills [logs], bed material sizes as governed by slope; drop structures to stabilize the channel gradient; riffles, pools, riprap, floodplains and backwater rearing areas in abandoned channels);

(2) Habitat specific structures installed to create diversity and to meet specific life stage needs of the fish (such as isolated and clustered boulders, flow deflectors, drop structures to trap spawning gravels and/or create rearing pools, deflectors to control the thalweg and create depth diversity, and access to backwater rearing areas); and

(3) Features which accelerate the natural rate of habitat development (such as introducing spawning gravel, bank shaping and revegetation or seeding, and introducing overhanging shore cover and woody debris).

Over time, the structures installed to stabilize the channel (Category 1) will deteriorate, but by then the channel will be adjusted to a more diverse state, and stabilized with vegetation, woody debris and natural bed and bank armoring. The habitat criteria for the project, as provided by Nez Perce National forest are listed in Table 18.

Description of Habitat Features

Category 1: Channel Hydraulic Design Features

1.1: Streambed Elevation Control Logs (Fig. 21)
Functions.--set a predetermined elevation on the channel bed; hold elevations at changes in channel gradient; stabilize cross-sections in bends; provide same function as natural woody debris.

Applications.[1]--at places where bed elevations are to be stabilized; in bends.

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1 See Drawing B at back for orientation and stations, and other subsequent figures.

Table 18. Habitat Criteria for Potential Restored Meanders*

Symbol	Description	Units
P:R	Pool to Riffle Ratio	60:40
SG	Spawning gravel sizes sorted in riffles	1-3 in.
PD	Pool depth	2-6 ft
RV	Streambanks suitable for revegetation	
B	Boulders for cover and flow deflection	
BV	Bank vegetation	
S	Stream shading	
UB	Undercut banks	
SW	Slackwater in pools and/or backwaters for rearing	

*Received from Don Hair, Nez Perce National Forest, 7/20/84.

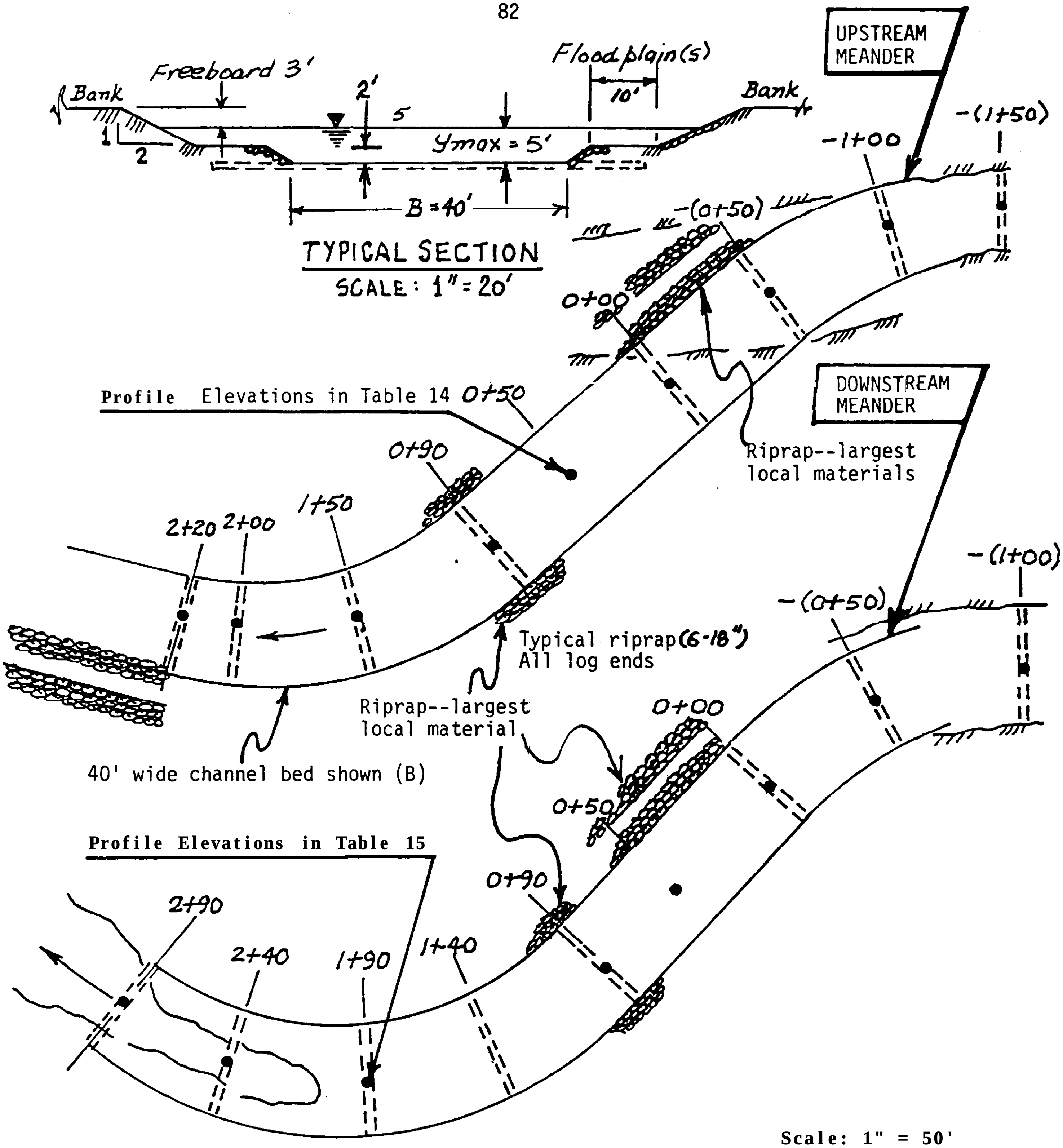

Fig. 21. Buried logs set to control bed elevations on bends and at changes in gradient.

Characteristics --9- to 12- inch logs with hardware cloth or filter blankets buried upstream; no mud sills; set flush with bed; imbed 8-10 feet in bank; riprap shore ends; set in series on same gradient as channel.

1.2: Drop Structures (Fig. 22)

Functions .--stabilize channel at high flows; dissipate energy in drops and pools to hold channel gradient; provide habitat in the form of pools, cover, rock interstices and spawning gravels up- and down-stream.

Applications. --from outlets of Pond No. 1 (Upstream Meander) to existing stream channel (Stas. 4+00 to 7+50); and from Outlet of Pond No. 8 (Downstream Meander) to existing stream channel (Stas. 4+90 to 7+90).

Characteristics .--larger (18-24 inch) single logs (or three, g-inch) with mud sills and hardware cloth or filter blankets upstream; set on design elevations based on channel gradient at tops of logs; ends imbedded 6-8 feet into bank; use riprap on ends and deadmen if not buried deep; or use K-dam construction if desired to create more diversity in habitat downstream; notch logs in center for passage flow (see design of weir in Table 19).

1.3: Riprap (Figs. 21, and 22)

Functions .--integrated, larger rock placed in a continuous area to protect a reach of shore, or a structure, from erosion is the main category of riprap. The ends of the control logs and drop structures mentioned earlier are protected with riprap. Local large, loose rock should be placed downstream of the drop structures to armor the pools. Provides additional interstitial cover for rearing.

Applications. --along the outside bank of bends; on faces of fills which are at the outside edges of the flood plains; heavy applications for about 60-80 feet downstream of bends (e.g., Sta. 2+20 - 3+00 on Meander No. 1) because of shear concentration there.

Characteristics .--use largest available local cobble materials, 6-9 inches for most applications; place on top of graded materials on bank slopes; use quarried larger rock (graded 6-24 inches) downstream of bends on outside banks at toes, with local cobble uphill from toe. Quarried rock (6-18 inches) should be used for shore riprap downstream of drop structures. Local cobble can be used for armoring pools downstream of drop structures.

1.4: Flood Plains (Fig. 21)

Already discussed in detail.

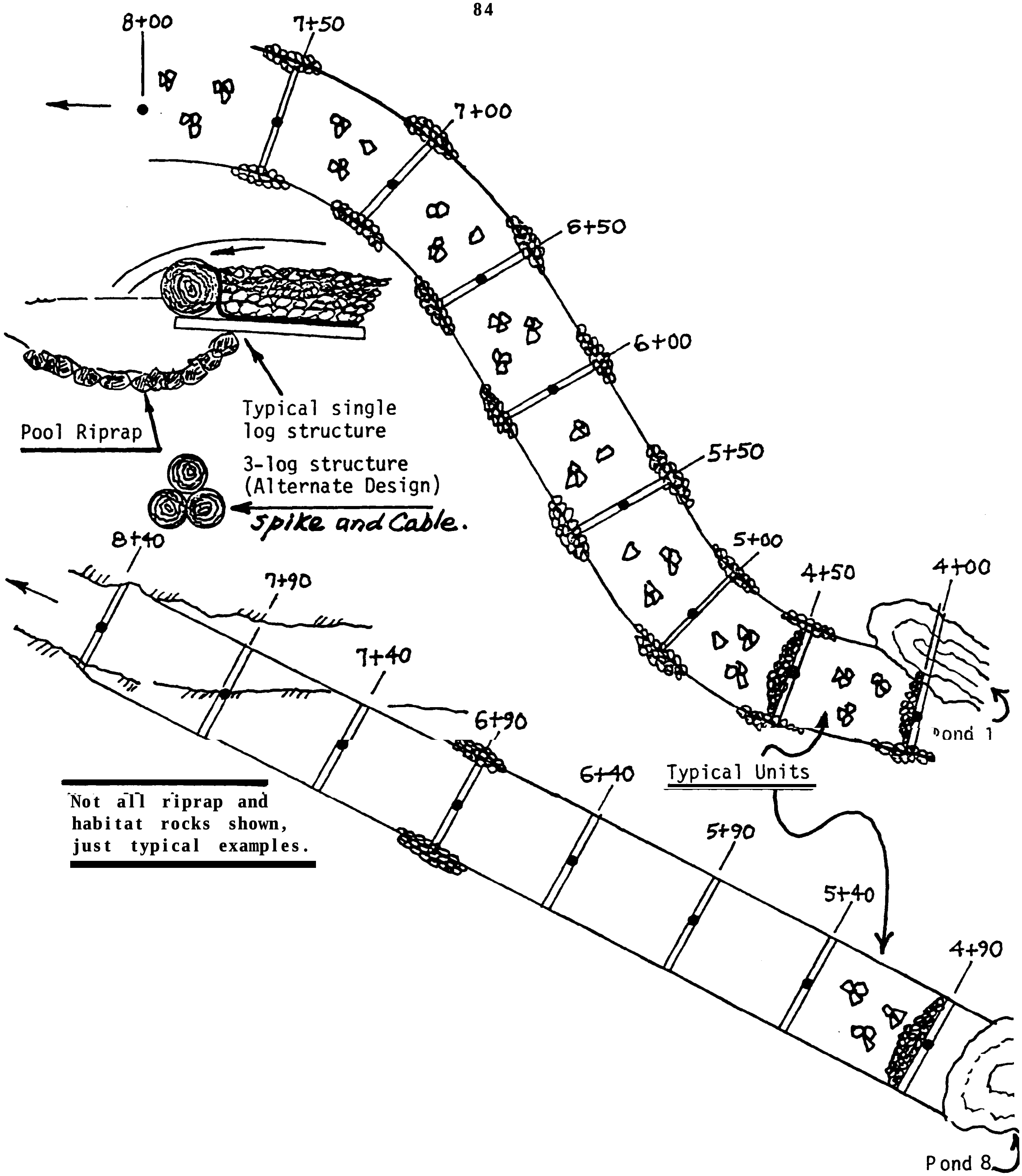

Fig. 22. Location of Drop Structures, End Riprap, Pool Scour Riprap and Boulder Clusters.

1.5: Backwater Rearing Areas (Fig. 23)

Functions.--provide appropriate scale of velocity, cover and food for rearing fish; provide secure area during high water for smaller anadromous and resident fish; encourages accelerated vegetative growth; accumulates woody debris; accumulates fine sediments.

Applications.--just upstream (south) of the downstream ends of the two meanders in the abandoned sections of the existing Crooked River channel. Seepage from the underground system will feed these areas, even during low flow periods. High water will keep access channels open, deposit silts and floating debris to create nursery areas.

Characteristics.--previously described. Can add woody debris from east shore. No special design features required. Will function naturally.

Category 2: Habitat Specific Structures

2.1: Boulders (Figs. 24, 25, and 26)

Functions.--singly (Fig. 24), in clusters of two to five (Fig. 25), or in larger clusters to serve as deflectors (Fig. 26), or arranged in a V-shape to trap spawning gravels; single rocks and groups usually cause scour downstream and roughen the water surface in their wakes, both of which provide cover and feeding zones; clusters form more diverse habitat; control thalweg as deflectors (Fig. 26). Due to a lack of large local rock, V-shaped gravel trapping structures constructed of rock are not recommended. The scour/ deposition pattern around single boulders and clusters depends on their position with respect other boulders and the streambanks.

Applications.--place 10 or so on an irregular line at center line of curves, with one rock spacing between, to stabilize on erosion of outside bank (Fig. 27); place groups of 3-5 downstream of tailout below dropstructures (Fig. 22); place larger boulders in Ponds Nos. 1 and 8, in groups of 3 to provide habitat and to move sediment through the pond; and maintain thalweg where it crosses from the outside of one bend to the outside of the next bend (Fig. 26).

Characteristics.--for single boulders (or clusters) use those with minimum dimension of 2-3 ft.; do not block more than 20% of the channel width at any transect; keep deflectors low and sloping down towards the channel, and pointed downstream at 30" angle from shore; build up deflectors of 1- to 2-foot rock with larger materials on upstream side and along toe; and do not place boulders or clusters any closer to an erodible shore than two times the width of the single boulder or cluster (unless you want the shore to be eroded). Do not place boulders on the inside of a bend where they will be buried.

2.2: Drop Structures.--same as Feature 1.2.

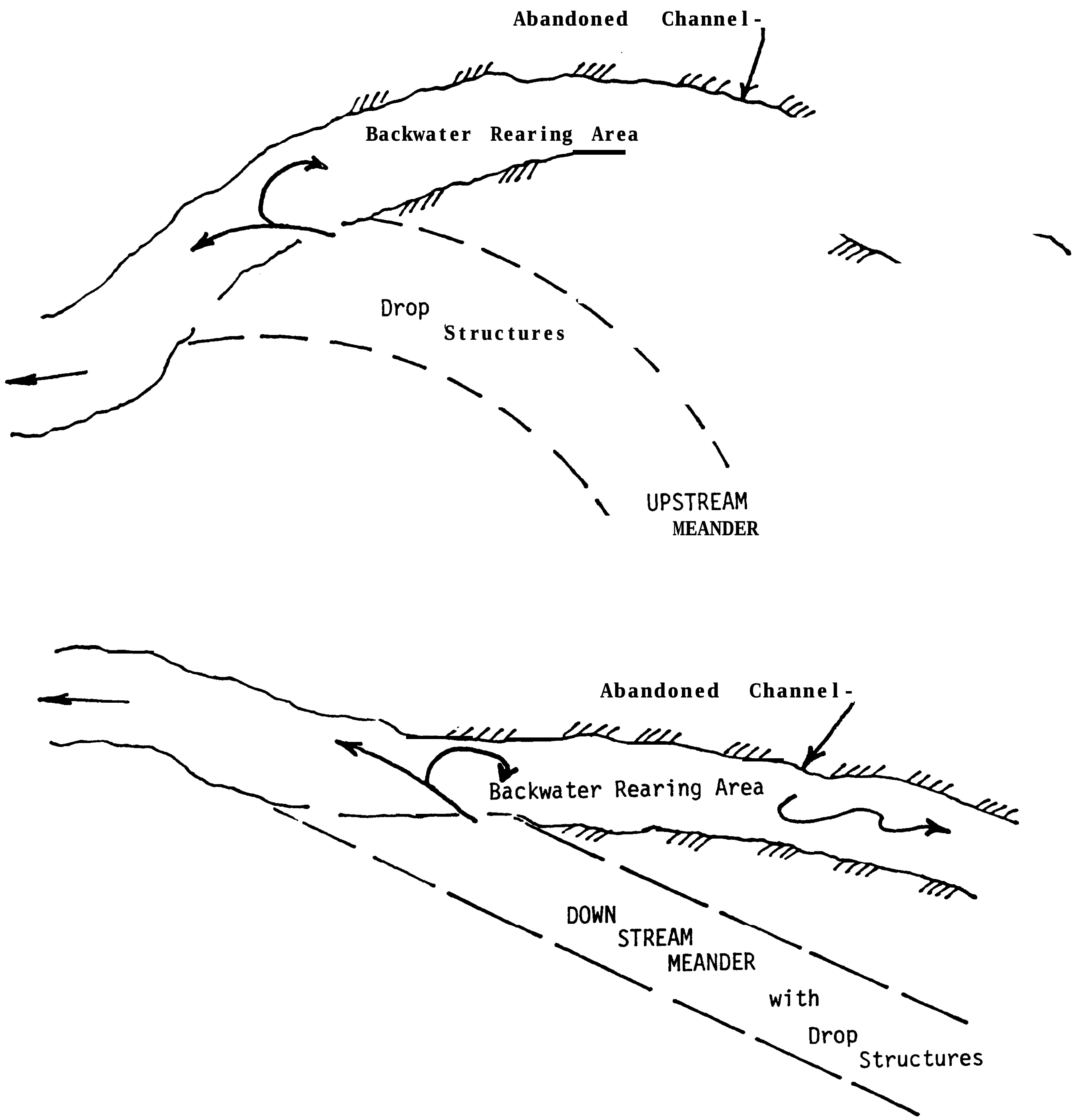

Fig. 23. Backwater Rearing Areas Upstream of Meander Junctions with Abandoned River Channel.

Fig. 24. Single, six-foot boulder in St. Regis River, Montana. Flow from right to left.

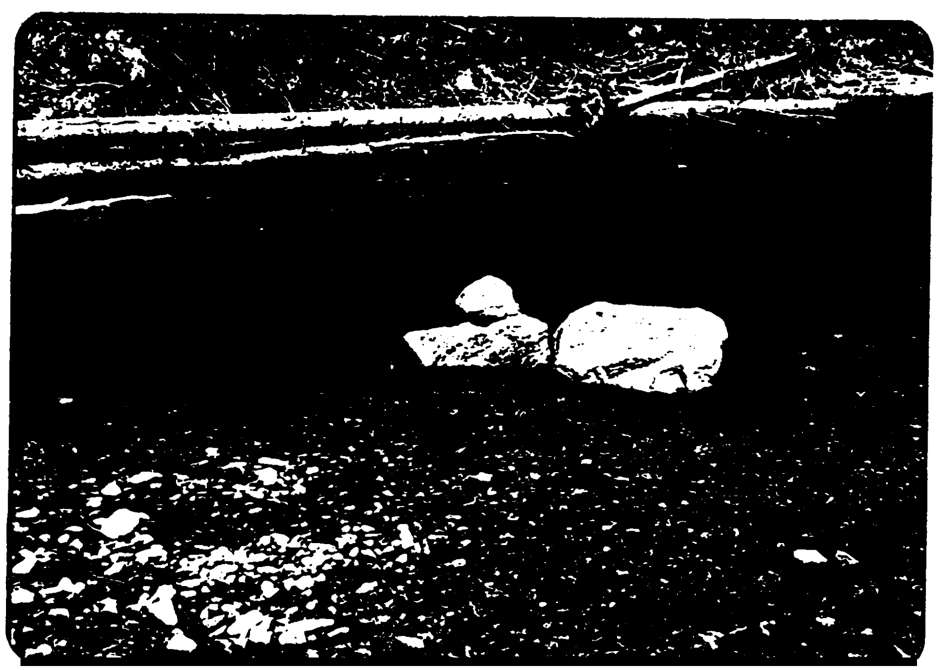

Fig. 25. Cluster of three boulders in St. Regis River, Montana. Flow is from left to right.

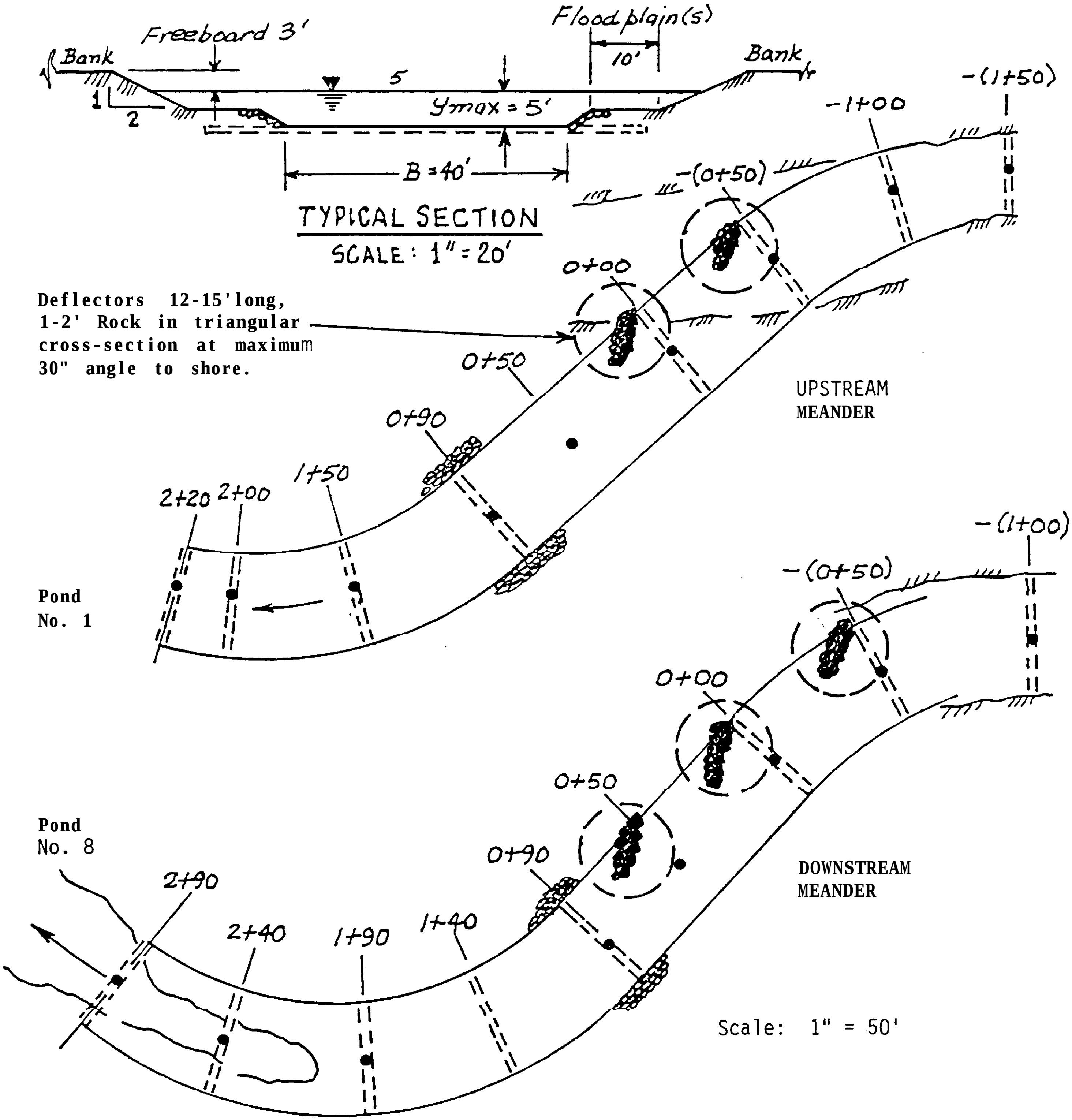

Fig. 26. Deflector rock groups to create pools for rearing and to deflect flow to the opposite bank.

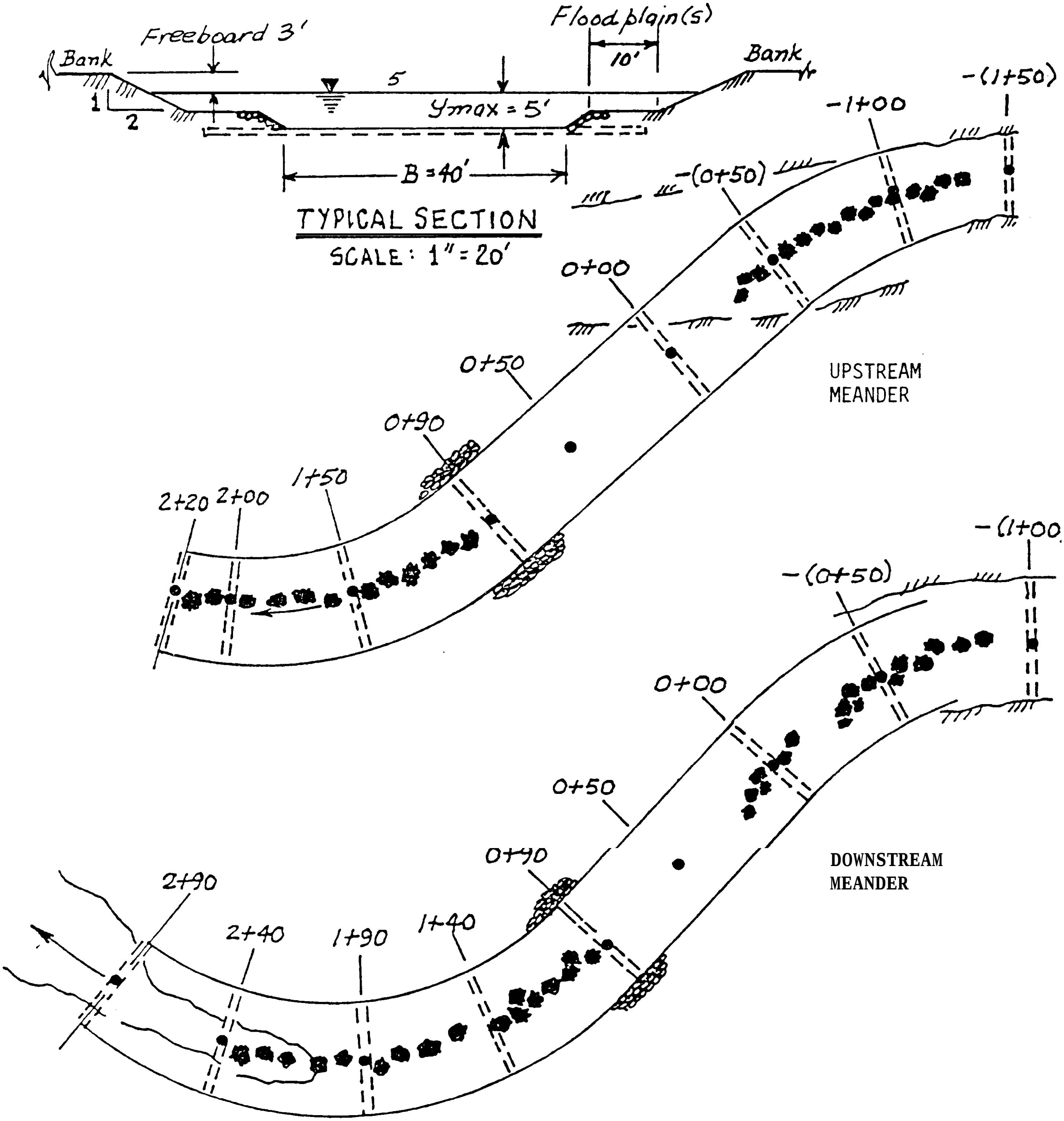

Fig. 27. Two- to three-foot boulders in staggered alignment near centerlines of meander bends to stabilize the channel, and provide diversity and rearing habitat. Note spaces for deflected flow (use with Fig. 26).

2.3: Deflectors. --can be made of larger rocks and or logs, and the same as described in 2.1 as Boulder Deflectors.

2.4: Backwater Areas. --same as Feature 1.5.

Category 3: Accelerating Features

3.1: Placing Spawning Gravels

By including a gravel sorting and mixing operation in the project, ideal spawning gravels (18-in. deep) could be placed in the 1% and 1.5% reaches of the meanders. Otherwise, it may take several years or more (depending on the amount of flooding) for enough sorting to take place to provide the required depth and size distribution.

3.2: Bank Shaping and Re-vegetation

Bank shaping is accomplished under the hydraulic design of the channel with gradual (2H:1V) side slopes, flat floodplains and 2:1 slopes on the embankments. Re-vegetation with willows buried under the bank materials, earth and native grasses will be a matter of choice. A few flood seasons will cause a dramatic change in the character of the riparian zone.

3.3: Overhanging Shore Cover

Logs anchored into the bank to form overhanging cover has been used successfully in dredged areas (Boland, 1984). A log deck, or filter fabric over log supports, can be used to cover the overhang, and sediment or grass clumps placed on top will encourage riparian vegetation.

In this project, riparian vegetation is being installed, and encouraged by building lower than usual flood plains. Also, cover is being provided behind builders and deflectors, under drop structures and in pools, as well as in the backwater rearing areas among aquatic vegetation and beneath woody debris. therefore, overhanging log bank structures are probably not needed for this project.

IX. RECOMMENDATIONS AND CONCLUSIONS

During the course of the project, as more information became available, several changes in habitat enhancement strategies were considered:

(1) Do not build the meanders;

(2) Build the meanders as designed under the constraints of matching them to existing ponds and swales, and avoiding the west side of the valley where the road is located;

(3) Instead of building the meanders, construct a flood plain on the left bank, and install a new suite of habitat improvement structures in the existing channel; and

(4) build an irregular, more "natural," rough channel with a wide flood plain upstream of the project site and upstream of the lake just north of Orogrande.

The main risk involved in each of the alternatives except number (3) (fixing the existing channel) is the potential loss of the stream flow by seepage through the banks and bed of the new channel. Over time the seepage would become clogged. To save this time, gravel and sand can be stockpiled, and placed in observed seepage areas when water is initially diverted into the new meander channel.

If spawning and rearing habitat for salmonids is to be improved soon in Crooked River in the project reach, obviously alternative (1) (Do Nothing) has to be dropped.

The second alternative (two meanders north of the airfield) is the recommended design for this project. The habitat improvement features, and hydraulic control structures will provide instant habitat. Also, over time, the lower-than-usual flood plains will accumulate silt, vegetation, and woody debris! The vegetation will stabilize the banks and encroach on the channel, causing it to be deeper and narrower than the initial channel. In addition, the abandoned sections of existing stream channel will provide excellent rearing areas which would not be available using the existing channel in option number (3).

The fourth alternative was discussed with representatives of the Forest Service and the Idaho Department of Fish and Game on March 15. The main difficulties of merely cutting a random channel through the dredged spoils, without using hydraulic design considerations and habitat structures are:

(1) The channel will be very unstable from year to year, and continually adjusting;

(2) The amounts and types of habitat will change from one high flow season to the next;

(3) There will be little opportunity for riparian habitat to develop unless it would be in small, transitional areas: and

(4) The initial amount of good habitat available would be relatively small compared to the two meanders north of the airport at the proposed site.

There is no way to balance or equate the development of readily available habitat to the amount of yardage (cut and fill) moved in excavating a channel through piles of gold-dredge spoils. The tools which are available are the site conditions (plan and profile), how the channel pattern and cross-section looked prior to dredging, and the basic principles of hydrology, hydraulics and river mechanics. All of these factors have to be matched to the needs of the species in question to develop "a design" for each site in question. Examination of several sites could lead to the development of more direct methods for developing meander restoration channel designs at other dredge-impacted sites.

This is why the project team from WSU supports either Option 2 of building the meanders, or Option 3 of improving the existing channel with a flood plain and a suite of new habitat structures. Excavation of the one-sided flood plain for the existing stream will be less expensive than cutting the two meander channels. Habitat improvements will be a little more expensive in the existing channel because there will need to be more of them on the steeper channel.

The main feature in favor of the two new meanders is the fact that the channels will recover to a more natural, stable, meandered state (with excellent habitat) in a much shorter time period than the other two channel options.

Following is a series of conclusions resulting from the project study:

(1) The proposed meanders would increase the length of the channel, and provide more natural meandering, but not enough length to provide more natural increase, nor an irregular meander pattern;

(2) Routing the meander channels through existing ponds and swales does not significantly reduce the required meander excavation volume, but adds pool volume;

(3) The designed meander patterns cannot be increased any more in length, by extending them to the west, because they would have to be build on fill, and the road would be lower than the channel; the channel would interact also with the west side surface drainage system of channels and ponds;

(4) There is a very heterogenous ground-water/river flow system, and constructing a new channel would increase the risk of losing the streamflow due to seepage unless the channel was sealed; although the existing channel has some seepage gains and losses, it does maintain a flow even during the dry season;

(5) Excavating the flood plain on the left side of the existing channel, as opposed to excavating the meander channels, would require roughly one-half the amount of excavation of the two meanders;

(6) The existing channel has shade, some overhanging banks and a woody debris supply all along the steep east bank, plus some vegetation and a small amount of flood plain along portions of the west bank.

(7) The meander channels would be relatively bare of streamside woody debris, and would require some years to establish a riparian supply (except for drift from upstream or artifically introduced debris);

(8) Several offstream-rearing areas could be constructed in low lying areas west of the existing channel;

(9) The plan view channel patterns are very similar between the existing channel and the proposed meanders, especially in the downstream reach and meander;

(10) A more irregular (natural) channel pattern cannot be developed at this site by merely excavating a rough channel with steep side slopes through the spoil piles and letting it adjust over time;

(11) The crucial hydraulic element in the development of a "more natural channel" is the existence of a flood plain to handle overflow and develop riparian habitat;

(12) A more natural, irregularly meandering channel could be more readily developed in the downstream reach of Crooked River near the mouth where the 90° bends have been dredged in conjunction with placer mining. Here the meander pattern is established, although too frequently; also, there is significantly more rearing and spawning habitat available. This reach would require a relatively minor amount of effort to achieve the desired natural meander pattern, compared to the upstream site near Orogrande and the project site just north of the airfield.

Even though the conclusions show that the meanders are only marginally feasible in this reach of Crooked River, the study has led to the concept of restoring a floodplain on the existing channel which has not been previously considered. Also, the study has generated the following information which will be of future value to the Nez Perce Forest, and other Forests with dredged stream valleys to restore:

(1) Site topographic information:

(2) The regional channel design procedure;

(3) The hydrologic model which can be used in similar climatic provinces on the Forest;

(4) The method for in-depth analysis of alternatives which will provide guidance for other habitat improvement projects; and

(5) The planned comparison of the biological productivity in various existing study reaches, and the two meander reaches, should be of value in the future selection of habitat improvement methods.

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APPENDIX II

LOCATION NOTES FOR P-l AND P-2

MEANDER LINES

CROOKED RIVER SURVEY 10/24/84 1/2

JO - $\overline{\text{X}}$
KC - ϕ
TB - ϕ

P-1
UPSTREAM

New* upstream P-1 Line
(LOCATION NOTES)

P-1 LINE

Station**	Description	Remarks
		START UPSTREAM
0+00	Imbedded rock 3' W. of high River bank.	Orange spray paint on all stations and CP's & BM's.
0+50	Rock 12' E. of road (double track)	± 1'
1+00	Imbedded rock beside dead bush just off end of runway and W. of Rd.	± 1' Rd. is trail.
1+50	Small pine w/stake tied at top -- largest tree in swale.	
1+72	Rock on small rounded ridge of fill, 2' upstream from 1+72.	Regular stations 2+00, 2+50, 3+00 etc. shown on blue print. Elev's. related to original P-1 survey of 7/4/84.
2+22	Rounded ridge with rock d/s of 2 small cut pines.	
2+72	Small rock 3' E. of Road near S. end POND # 1.	Near orig. P-1 survey Sta. 2+71

* Resurveyed because original surveys destroyed by unknown person(s) with only CP-7, CP-8, CP-10 and BM-3 remaining. ALL CONTROL POINTS CAIRNED.

** Refer to Blueprint Site Drawing for alignment and location(s).

JFO 2/5/85

CROOKED RIVER SURVEY - Cont'd. 10/24/85 2/2
JO π
KC, TB φ

New Upstream P-1 Line:

Station	Description	Remarks
3+22	Large rock in clump of horsetail.	
3+72	12' d/s of loge pole trimmed next to constriction in Pond #1.	
4+22	Near base of tree that was cut down on route.	
4+72	9.5' S.E. of 6" Pine, 20' high w/ blaze and 22.5' N.W. of 8" Pine, 25' high w/ blaze. Painted rock.	Same point as CP-21 in survey notes.
5+00	Bottom of swale. Painted rock.	
5+50	In middle of 3 small pines.	
6+00	u/s of 2 trimmed pines on steep dredge pile opposite large fir tree.	
6+50	In wooden shack debris 16.5' N. of 3" Pine, 15' High; 34.7' E-SE of 12" Pine, 40' high.	Same as (nr.) CP-20. Red rock.
7+00	Top of Rock pile near river bank.	
7+50	17' E. (beyond) blazed and painted dead willow. Near old CP-6 on bar.	

CROOKED RIVER SURVEY 10/24/84 1/

JO - π
KC - ϕ
TB - ϕ

P – 2 LINE

New Downstream Meander Location Notes*

STATION	DESCRIPTION	REMARKS
0+00	Imbedded rock 9' upstream from two large rocks on left bank.	Orange spray paint on all stations.
0+50	2 ft. east of painted rock opposite dead willows on steep bank.	This P-2 line will need to be resurveyed from CP-24 on N. side of POND No. 8 back to Sta. 1+78 to 0+00.
1+00	2 ft. downslope from large rock on top of large mound. In line with 3 pine on downslope.	
1+50	2 ft. towards river from large rock on N. slope of large swale leading to small pond South of Pond No. 8.	Transects will need to be surveyed at all stations on P-2 line.
1+78	Large rock on west bank of depression leading into the small pond.	

Notes on meander channel from North end of Pond No. 8 to Crooked River on page 2.

* See drawing A for meander line layouts.

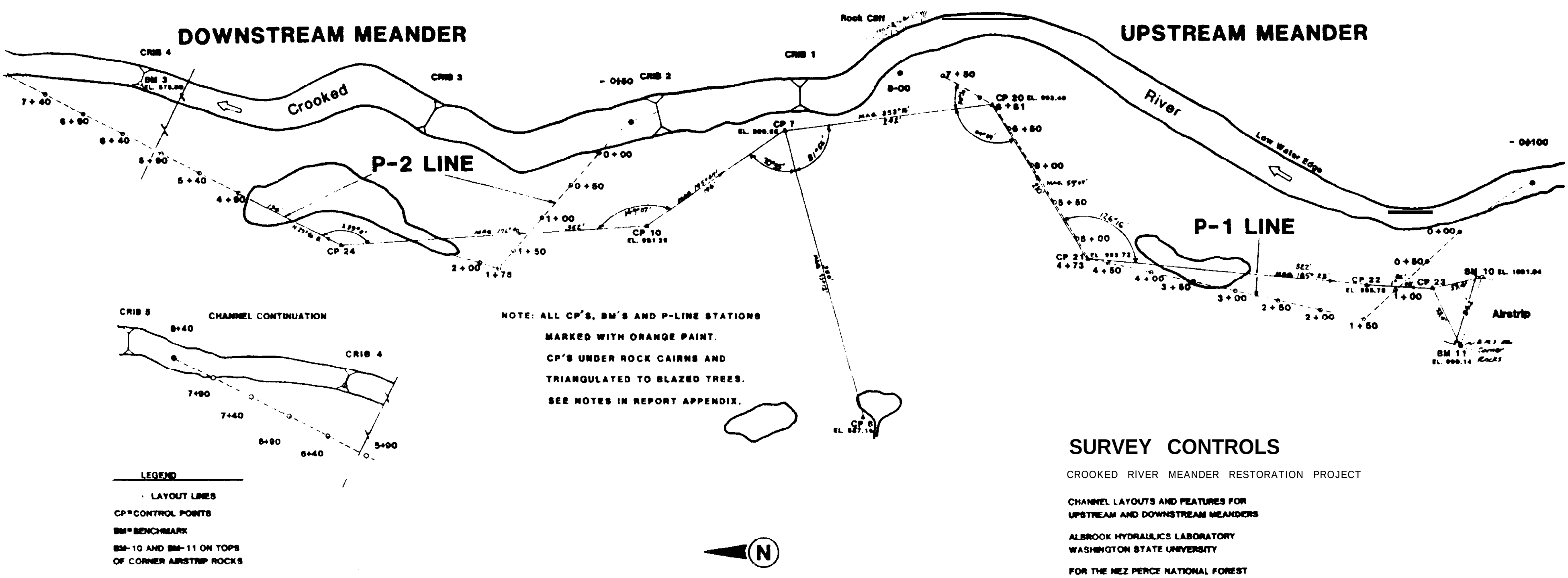
Meander Route from Pond No. 8 to Crooked River

Stas. 4+90 to 7+90

STATION	DESCRIPTION	REMARKS
4+90	N. end of Pond No. 8 Large rock on ℄ of pond.	Orange spray on all stations
5+40	3 rocks in line opposite 2nd large lodgepole N. of Pond. Spot on imbedded rock.	
5+90	Large rock on steep slope into small pond on right; just above small bush.	
6+40	1 ft. from imbedded rock among 4 blazed pines.	
6+90	Rocks on south slope of large swale just beyond trees.	
7+40	Imbedded rock on steep side slope, 4 ft. from top of pile.	
7+90	150 ft. downstream from BM #3 on Crib #4. Large rock 2 ft. upstream from large bush.	

A

DRAWING A - FINAL SURVEY CONTROLS



SURVEY CONTROLS

CROOKED RIVER MEANDER RESTORATION PROJECT

CHANNEL LAYOUTS AND FEATURES FOR
UPSTREAM AND DOWNSTREAM MEANDERS

ALBROOK HYDRAULICS LABORATORY
WASHINGTON STATE UNIVERSITY

FOR THE NEZ PERCE NATIONAL FOREST
ELK CITY, IDAHO

JANUARY, 1985

SCALE: 1" = 50' ROUTE SURVEY ON 10/20/84

SEE REPORT NOTES AND CONTROL TRIANGULATIONS.

B

DRAWING B - TYPICAL TRANSECTS

MEANDER CHANNELS-PROFILES AND TRANSECTS

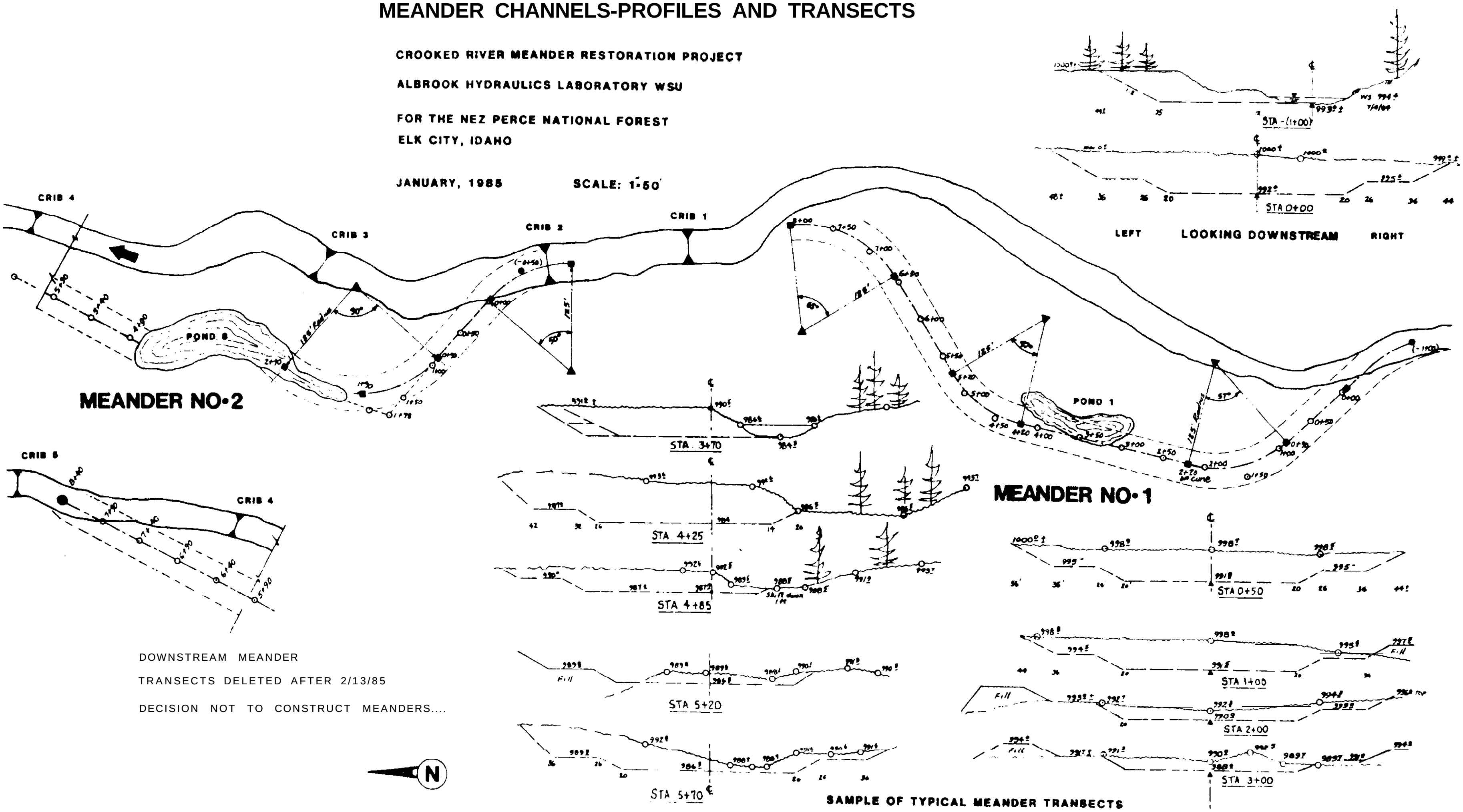
CROOKED RIVER MEANDER RESTORATION PROJECT

ALBROOK HYDRAULICS LABORATORY WSU

FOR THE NEZ PERCE NATIONAL FOREST

ELK CITY, IDAHO

JANUARY, 1985 SCALE: 1"-50'



DOWNSTREAM MEANDER

TRANSECTS DELETED AFTER 2/13/85

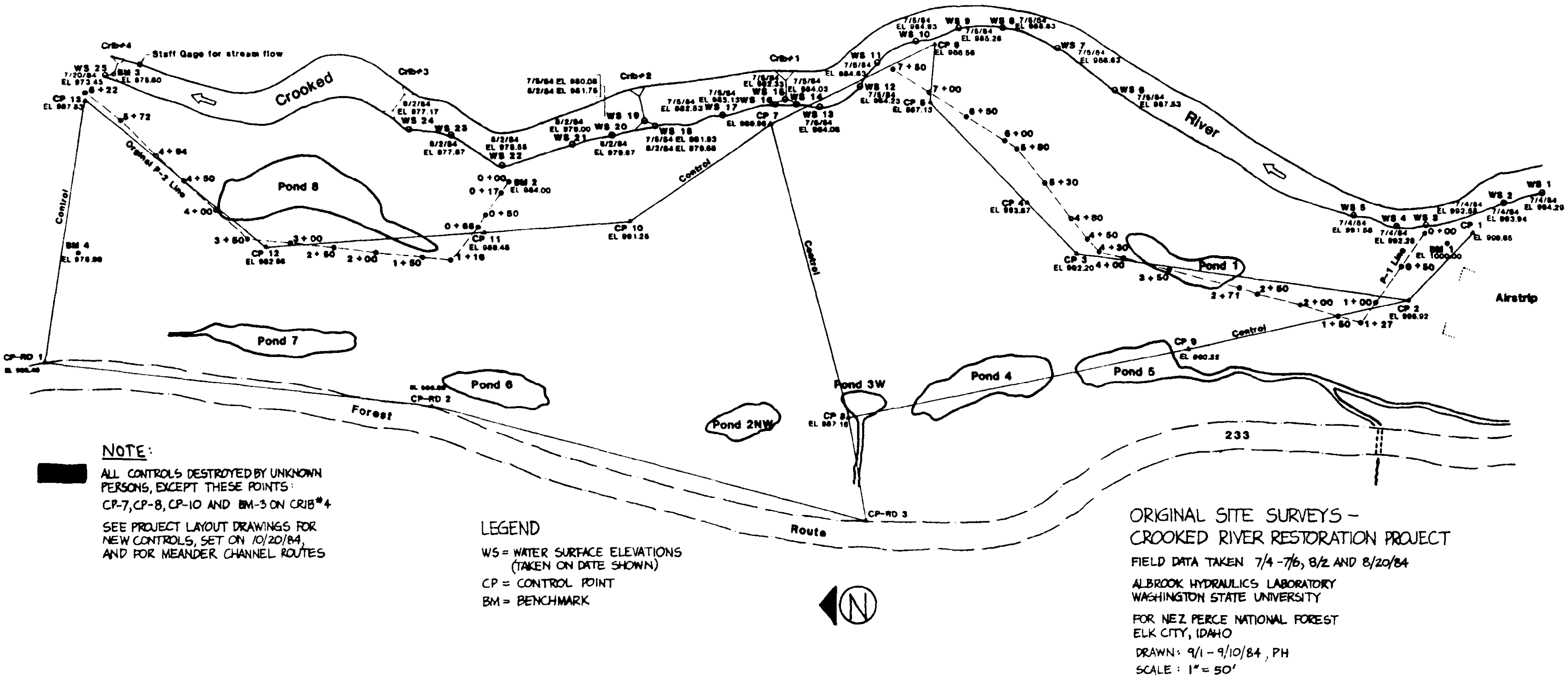
DECISION NOT TO CONSTRUCT MEANDERS....

SAMPLE OF TYPICAL MEANDER TRANSECTS

TRANSECTS: SCALE 1 10

C

DRAWING C - ORIGINAL SITE SURVEYS AND WATER SURFACE ELEVATIONS



SOUTH FORK CLEARWATER RIVER

HABITAT ENHANCEMENT

ANNUAL REPORT - 1984

By
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Rick Stowell, Project Coordinator
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Nezperce National Forest

Prepared for

Larry B. Everson, Project Manager
U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife

Agreement No. DE-AI79-84BP16475
Project No. 84-5

March, 1985

TABLE OF CONTENTS

INTRODUCTION

In 1927 a dam was constructed on the South Fork of the Clearwater River at Harpster, which totally eliminated anadromous fish runs into this important spawning and rearing habitat. In 1935 a fish ladder was constructed at the dam but was reportedly only minimally successful. In 1962 the dam was completely removed. By this time, however, the anadromous runs had been eliminated from the drainage. Additional activities in the drainage that have had impacts on the anadromous fish habitat include mining (both dredge mining and hydraulic mining for gold), grazing (especially on private lands in Red River), and timber harvest and road construction which have increased pediment loads in the streams.

Idaho Fish and Game began a program of re-introduction of anadromous salmonids in 1962. Hatching channels were constructed on Red River at the Red River Ranger Station and on Crooked River near Orogrande. These were stocked annually with eyed eggs. Species stocked varied and included coho salmon, chinnook salmon and steelhead. The Crooked River channel was abandoned several years ago when the lease on private land terminated; however, the Red River Channel has continued in operation. Most of the recent use (1978-1983) has been with steelhead. In 1977 Idaho Fish and Game constructed a rearing pond at Red River which is used to rear 200,000-300,000 spring chinook salmon annually. The pond is stocked with fry in the spring. After rearing in the pond over the summer, a portion are marked and all are released into Red River at the pond site.

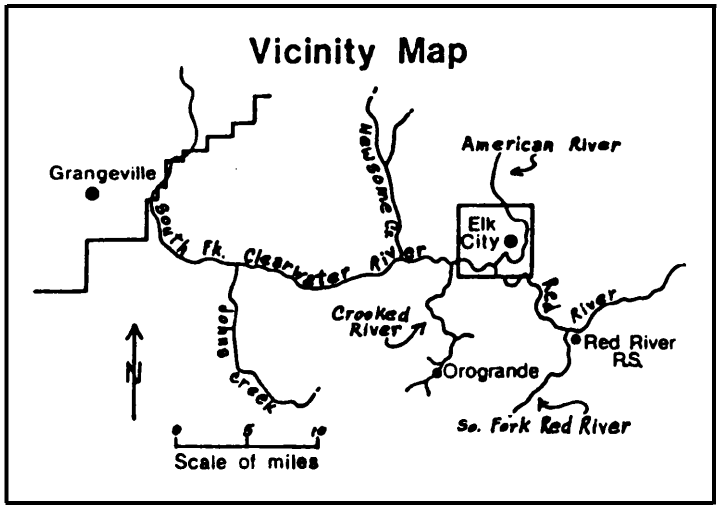
The U.S.F.S. began a program of active habitat improvement in the Red River, Crooked River, and Newsome Creek drainage systems in 1980. These are continuing on an annual basis utilizing Forest Service funding. Since the B.P.A. project proposal has been approved, the Red River District has directed its emphasis to the South Fork of Red River, and the Elk City District has concentrated on Newsome Creek. These projects will complement the B.P.A. work being carried out in Red River and Crooked River. The 1984 U.S.F.S. contribution to the rehabilitation of the South Fork Clearwater system was $41,000 (this includes $21,000 direct habitat improvement work and $20,000 for erosion control and rehabilitation of an old hydraulic mining operation).

__DESCRIPTION OF PROJECT AREAS__: The projects are on the Red River and Elk City Ranger Districts of the Nezperce National Forest (Figures 1 & 2).

The Red River project area consists of approximately 19 miles of stream with 50% on U.S.F.S. land and 50% on private land. Stream reaches involved include both meandering meadow reaches and timbered valley bottoms. Fish habitat problems are the result of overgrazing and previous dredge mining for gold. The Crooked River project area covers 10 miles of stream with more than 90% on U.S.F.S. land. Fish habitat problems are associated with past dredge mining activities for gold which channelized the stream channel and eliminated the riparian meadow.

FIGURE 1

Red River Fish Habitat Improvement Project



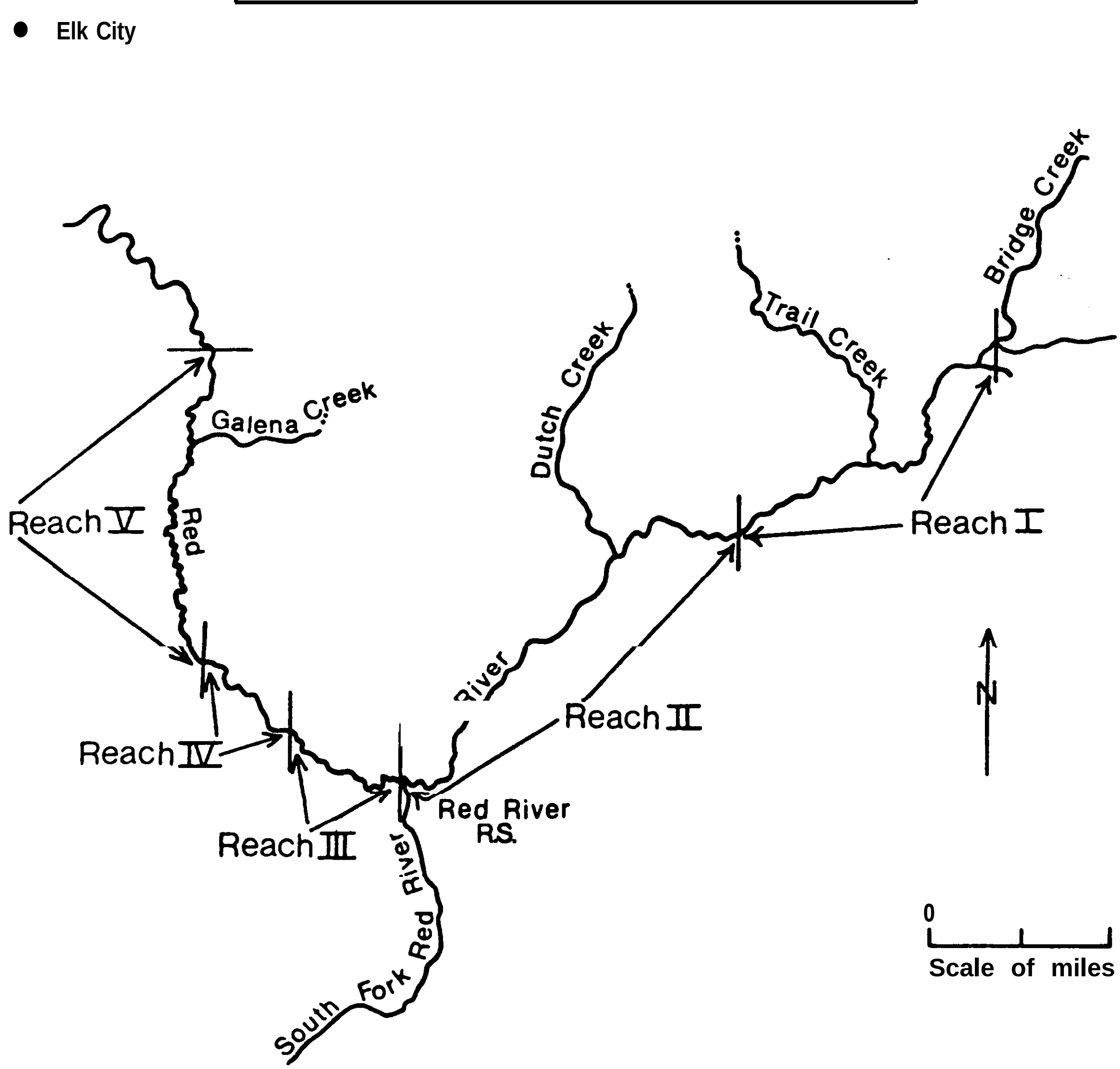
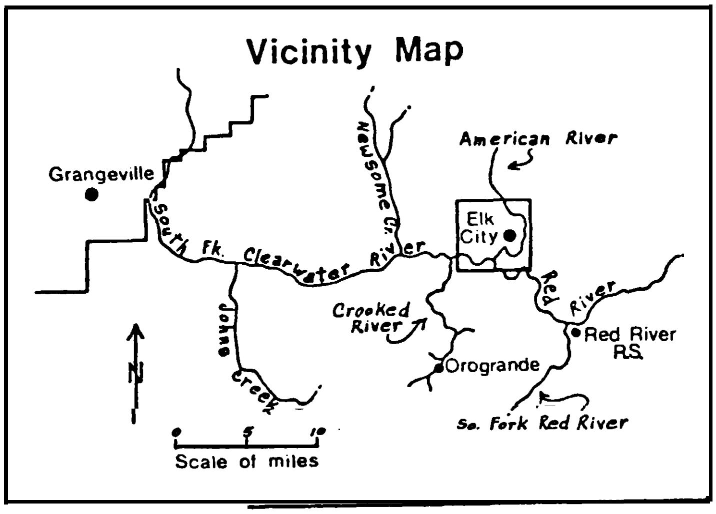
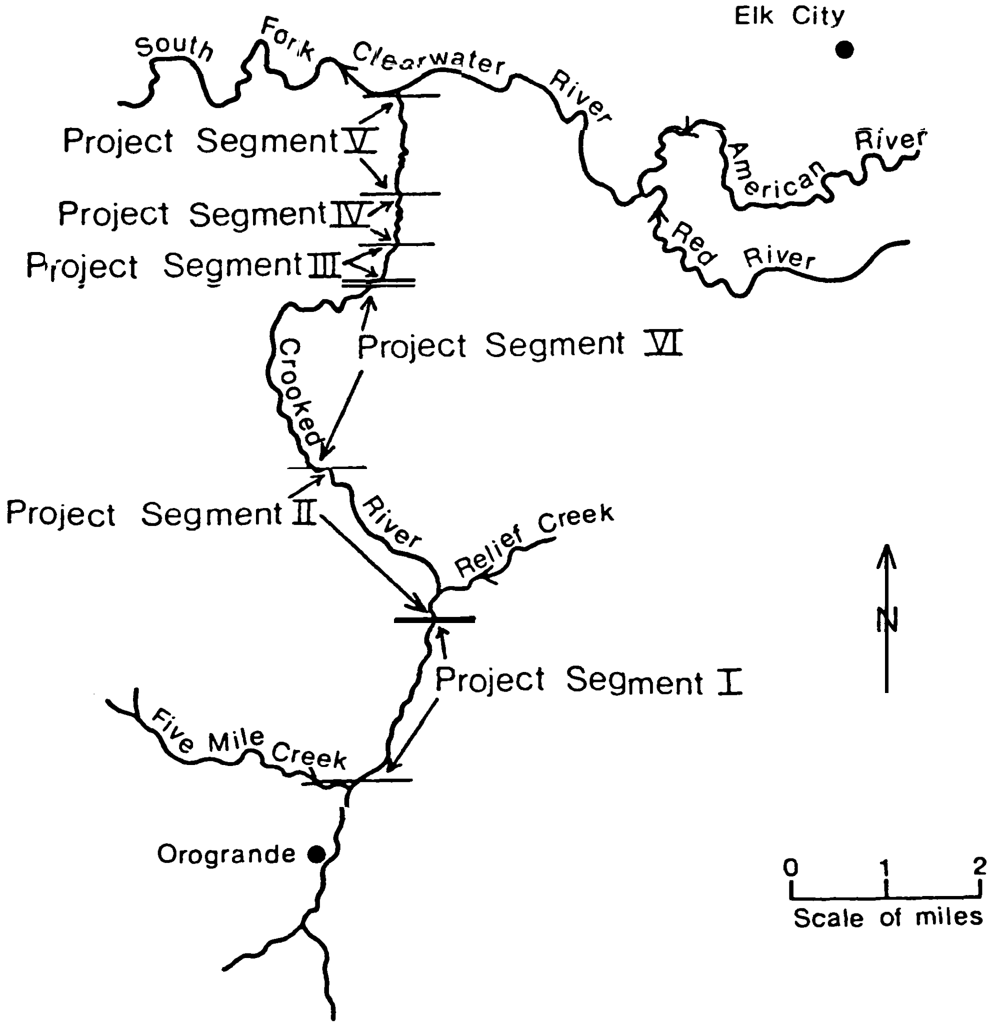


FIGURE 2

Crooked River Fish Habitat Improvement Project





METHODS

Because of the scope of these projects, and multiple land ownership pattern, it was necessary to develop a systematic approach for evaluation, design and execution of the projects. The first step was to separate the streams into reaches with similar characteristics. On Crooked River each reach was considered a project segment while on Red River each reach was separated into individual project segments based on ownership.

After stream reaches have been identified, each reach is evaluated for fish habitat problems and potential habitat improvement projects. The resulting project proposals undergo continuing review and revision until a final project design is selected.

Methods used in 1983 and 1984 were standard fish habitat improvement projects including log weirs, deflectors, bank overhangs, bank stabilization structures, riparian fencing, boulder placement and riparian vegetation planting.

Descriptions of the problems identified and various treatments of the problems follow.

Problem #1 - Streambank stability.

Beneficial fish habitat features related to streambank stability include undercut banks and overhanging vegetation (cover). Adverse effects from lack of stability include excessive bank erosion leading to sedimentation, widening of the stream channel, and shallower streams.

The following illustrate range of bank stability problems encountered, and treatments carried out on Red River and Crooked River during 1984.

TABLE 1

B.P.A./F.S. RED RIVER FISH HABITAT IMPROVEMENT PROJECT

Project Segment	Stream Length	Ownership	Improvement Opportunity
I-A	3600'	U.S.F.S.	Low
I-B	5100'	Private	Low
I-C	6000'	Private	High
I-D	3600'	Private	Low
I-E	2100'	U.S.F.S.	Low
I-F	9300'	Private	Low-Medium
Subtotal	5.6 Miles		
II	5.5 Miles	U.S.F.S.	Medium
III-A	2000'	U.S.F.S.	Medium
III-B	4300'	Private	Low-Medium
III-C	3300'	Private	High
Subtotal :	1.8 Miles		
IV	2.0 Miles	U.S.F.S.	Medium-High
V-A	2600'	Private	High
V-B	7200'	Private	High
V-C	4000'	Private	High
V-D	5400'	Private	Medium
V-E	1000'	U.S.F.S.	High
Subtotal :	3.8 Miles		

TOTAL: 18.7 Miles

TABLE 2

CROOKED RIVER SCHEDULE

ACTIVITY

Project Segment	Survey	Plan	Instream Structures	Bank Shaping	Riparian Revegetation
I	****	****	84-85	****	84-85
II	85	87	88	88	89
III	****	85	86	86	87
IV	****	85	86	86	87
V	****	85	86	86	87
VI	86	86	87	87	88

**** Completed.

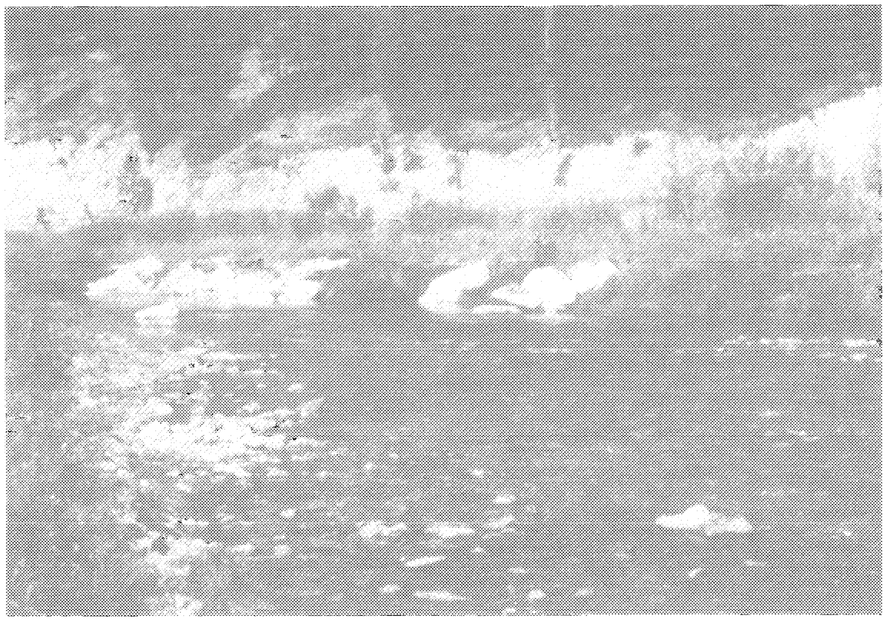
Example I - Red River

Description - This was a 3'-5' vertical, eroding streambank, It was a constant, source of sediment which adversely affected otherwise good spawning and rearing habitat located in this stream reach, Due to its over- -steepened nature it was not stabilizing and revegetating naturally.

Treatment - This site was treated by the crew using hand tools. Logs were placed at the toe of the slope and backfilled by hand with streambed rock, The bank was then cut back and shaped, seeded, fertilized, mulched and planted with willow cuttings,

Expected-Benefits - The treatment will reduce sedimentation, improve bank stability and increase coyer from the Logs and vegetation, This should improve both spawning and rearing in the immediate vicinity.

Example 2 - Red River



<u>Description</u> - These streambanks were eroding at intermittent intervals with good sections of overhanging vegetation and undercut banks in between. Raw banks were 1'-3' high in the eroding sites.

<u>Treatment</u> - Eroding sections had boulders and rock placed to stop erosion and protect the existing good habitat adjacent to these sites. The treated portions of streambank will have seeding, fertilization, and shrub planting done next spring.

<u>Expected Benefits</u> - The treatment will reduce erosion at the existing problem areas and protect the current existing good fish habitat features, such as undercut banks and overhanging vegetation. This will help retain the available rearing habitat, and with revegetation will increase rearing habitat in the future. This is in an area with suitable spawning gravels and may enhance the site for spawning by providing additional escape cover for spawning adults.

Example 3 - Red River

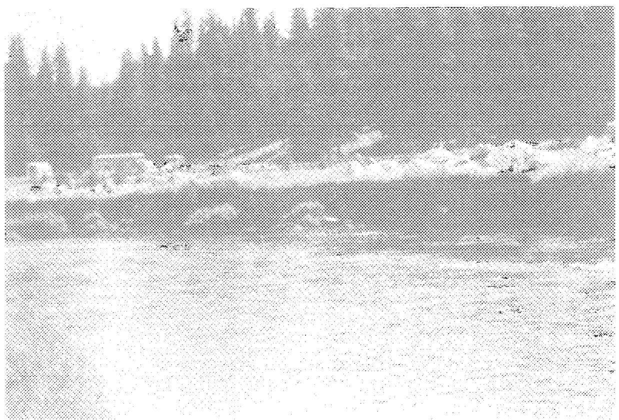
<u>Description</u> - These are 10'-20' high banks of overburden material left after removal so the area could be dredged for gold. Erosion has been occuring at the toe of the slope; subsequently the upper slopes are experiencing mass wasting and sloughing into the stream.

<u>Treatment</u> - The toe of the slope was protected with logs held in place with fence posts. Logs were then back filled with rock and sod. Upper banks were seeded and planted with trees and shrubs.

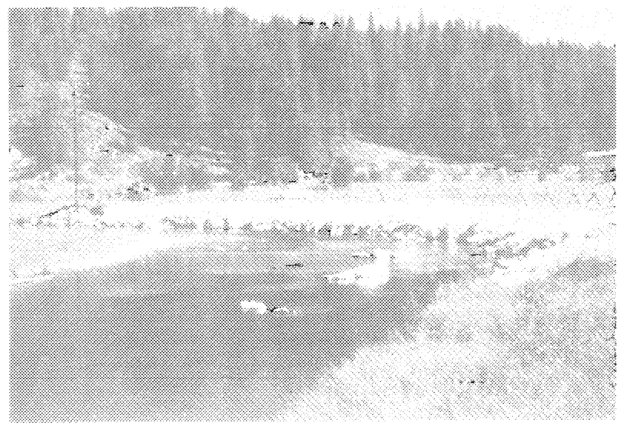
<u>Expected Benefits</u> - The treatment will reduce sedimentation and reduce rates of sloughing and upper bank failure. Deeper root mass of trees and shrubs should reduce mass wasting of upper banks. Logs will provide cover, thus improving rearing habitat.

Example 4 - Red River

BEFORE



AFTER



Description - These eroding banks are 4'-6' and 12'-15' high. The erosion has resulted in a stream channel that is too wide and shallow, and there is no instream or bank cover. Erosion of the upstream bank is threatening to cause loss of the power line pole.

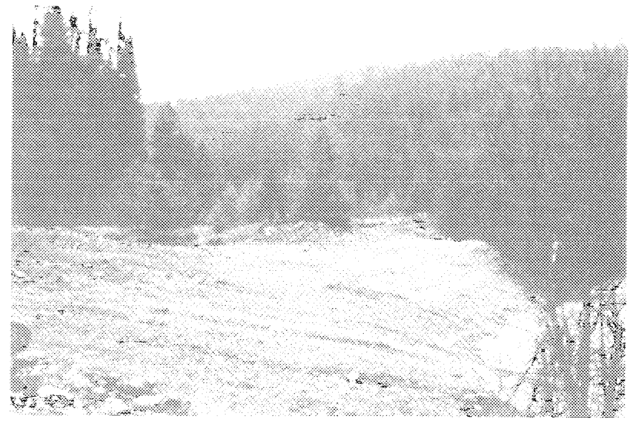
Treatment - Boulders were placed at the toe of the slope and back filled with streambed rock. Banks were then sloped to the rock with a backhoe, with final shaping by hand. All slopes were seeded and fertilized. High banks were covered with "Curlex" erosion control matting, and low banks were mulched with straw. Containerized shrubs were planted in the fall.

Expected Benefits - Reduce bank erosion will reduce sedimentation. Cover for rearing fish will be provided by the boulders. There will be increased cover from overhanging vegetation as a result of the revegetation efforts. Reduced erosion should reduce stream width and increase depth.

Example 5 - Crooked River

BEFORE

AFTER



Description - This is a section of dredge tailings remaining along the stream after dredging for gold. These were unstable and eroding at the toe of the slope during every high water. They were a constant sediment source; there was no cover being provided and no vegetation could develop.

Treatment - Tailings were pulled back with a D-7 dozer. Objective was to reduce the slope and height of the tailings. Treated areas were seeded and fertilized after shaping.

Expected benefits - Reducing the slope and height of the tailings sedementation, increased bank stability and improved site potential for revegetation. The new, lower banks will act as a "flood plain" which will help handle overflow and improve opportunities for riparian revegetation. Improved bank stability will increase the stability of the instream structures installed at this site.

Example 6 - Crooked River

BEFORE

AFTER

Description - This 6'-15' eroding bank was caused by the stream being moved during dredging operations and is a constant sediment source. The stream was too wide and shallow, providing little, if any, fish holding habitat.

Treatment - Streambed rock was placed at the toe of the slope and boulders placed on top. The bank was then shaped with a Cat 225 hydraulic excavator, seeded, fertilized, mulched and planted with containerized shrubs and trees.

Expected Benefits - Reduced sedimentation and increased rearing capacity should result.

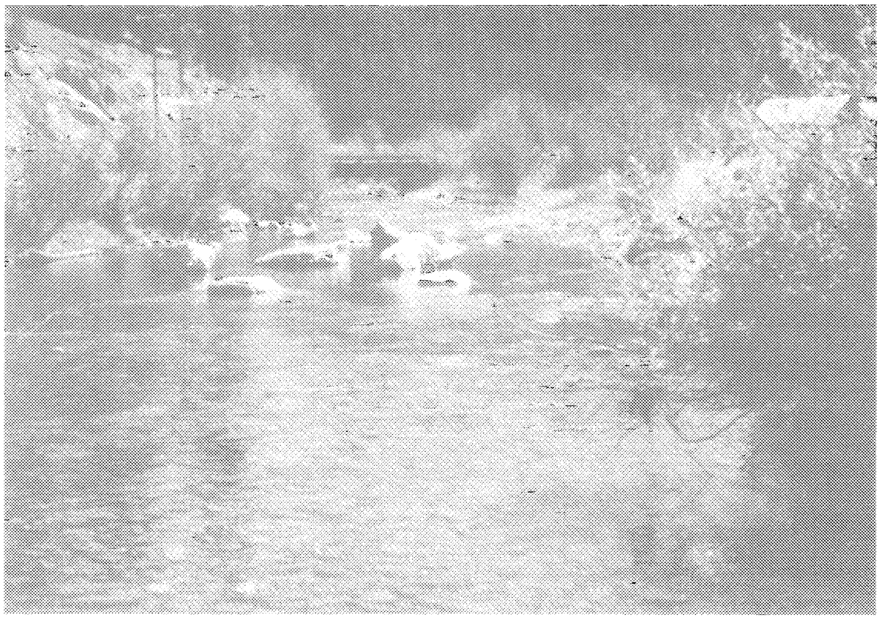
Problem #2 - Lack of instream cover.

This may be one of the most limiting factors in the project areas. Many things provide cover for fish of various ages. These include boulders, down trees, debris jams, overhanging vegetation, and undercut banks. In addition to providing cover, these objects act as flow deflectors which provide localized water velocities suitable for resting and /or feeding sites for fish. Presence of cover may also enhance the use of spawning gravels.

Activities undertaken to enhance cover included those designed for immediate benefit such as boulder placement, dropping trees into the stream, and constructing overhanging structures such as deflectors. Activities which will produce benefits farther in the future are primarily associated with riparian revegetation (grass seeding, fertilization, shrub and tree planting, and fencing).

The following are examples of treatments carried out this year.

EXAMPLE 1 RED RIVER



Description - This is a relatively shallow, open stream reach with no cover. There appeared to be no holding sites for either young or adult fish.

Treatment - Boulders were hauled in and placed, using a crane.

Expected Benefits - Boulders should provide both cover and reduced water velocity needed for resting and/or feeding sites for young and adult fish. Scour around the boulders should provide increased water depths.

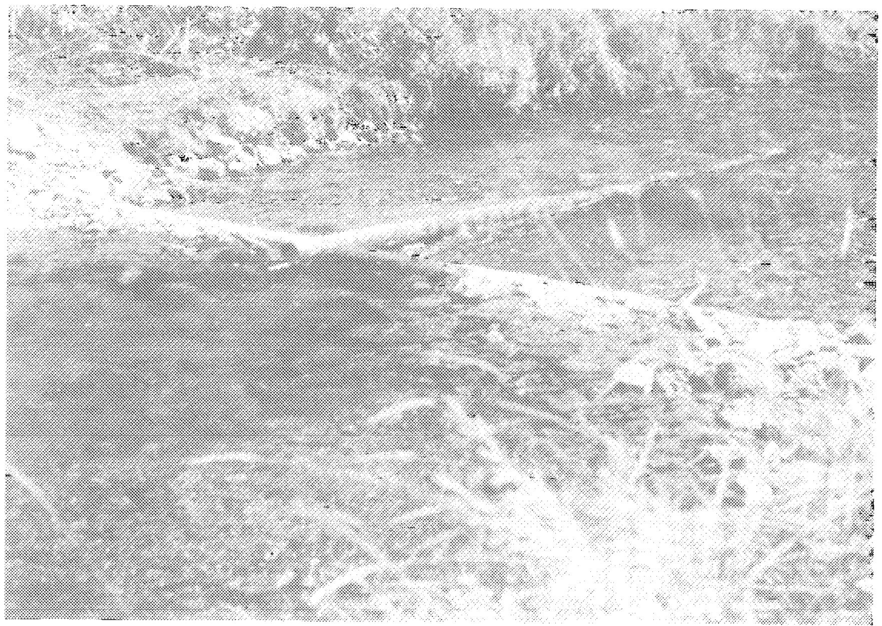
EXAMPLE 2   RED RIVER

Description - This is a relatively deep run (2' - 4') which lacked instream cover and provided little holding water for either young or adult fish.

Treatment - Boulders were transported to the stream and later placed using a crane. Boulders were placed both in the middle of the channel and along the bank.

Expected Benefits - Boulders will provide cover and feeding sites for young and adult fish.

EXAMPLE 3 - RED RIVER



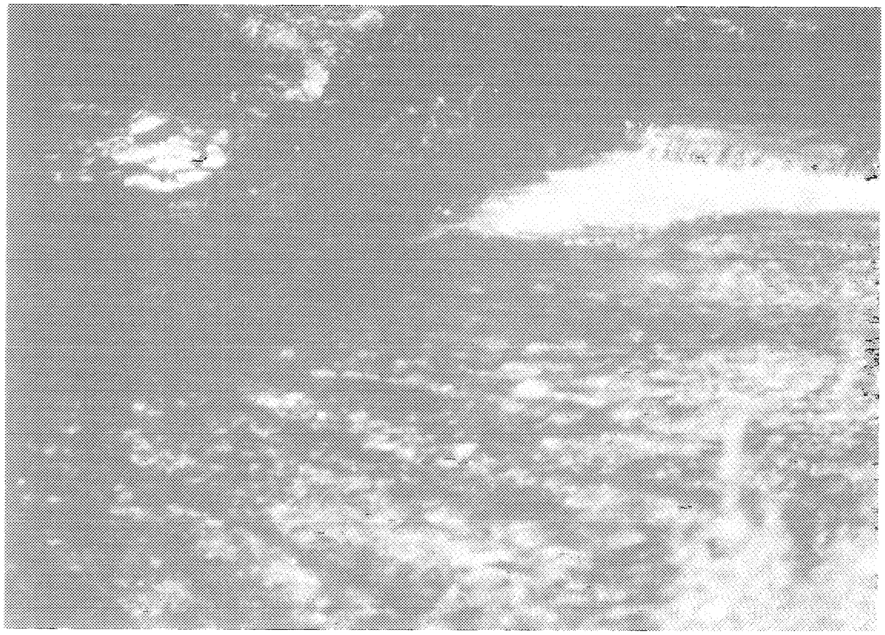
(Scour Hole with Overhead Cover)

Description - This was a relatively shallow run lacking instream cover.

Treatment - One log was placed perpendicular to the stream flow and buried into each bank approximately 5 feet. The log was back filled on each end with streambed rock, and a pool was excavated under the center portion of the log. A second log was attached at right angles to the first, and parallel to the flow. It was positioned adjacent to the main flow to provide cover for the most desirable holding site.

Expected Benefits - The structure should provide a desirable mix of depth, velocity and cover, particularly for age one and two steelhead thus increasing carrying capacity for rearing fish.

EXAMPLE 4 - CROOKED RIVER



(Tree Providing Cover Over Pool)

Description - This is the tailout of a pool created by installation of a log weir.

Treatment - After the log weir was installed a tree was positioned to extend downstream over the pool and following riffle. The tree was fixed in place by attaching it to the stump using 3/8" cable.

Expected Benefits - The tree will provide cover for both adult and young fish using the pool habitat. It also provides escape cover for fish using the spawning gravel at the tailout of the pool.

Problem #3 - Water Depths During Low Flow

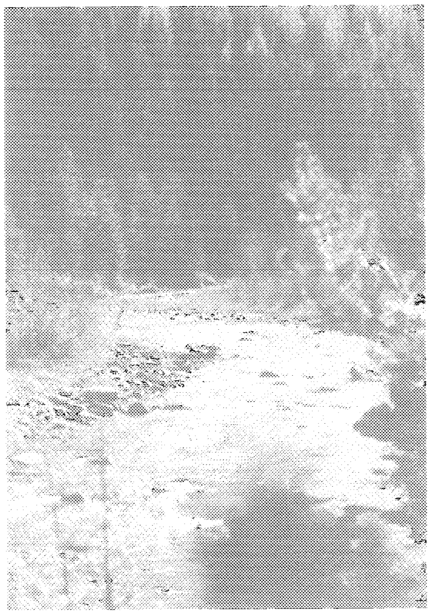
There are reaches in both Red River, and to a greater extent Crooked River where water depths is less than optimum for both adult and juvenile salmonids. Many times water velocity in the shallow reaches is too fast to be used extensively.

Our main approach in these sites is to build weirs, either with logs or boulders; and deflectors, primarily of rock. The design of these varies with the conditions at each site.

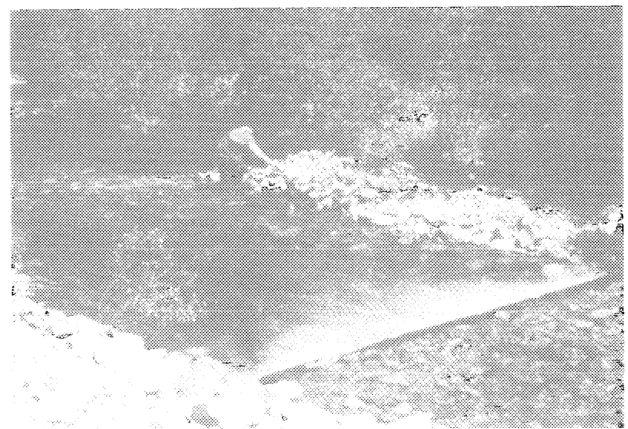
The following examples demonstrate most of the techniques used in the project this year.

EXAMPLE 1 - CROOKED RIVER

BEFORE



AFTER



Description - Sites selected for installation of log weirs were long reaches of shallow runs and riffles unbroken by pools or deep runs.

Treatment - The general sequence of activities used when installing log weirs was similar to that reported in other areas and will not be detailed here. Basically the weirs consist of trees placed perpendicular to the stream flow and anchored 10' into each bank. A 6' wide layer of 2" x 2" wire mesh covered with filter cloth was placed on the upstream side and buried below streambed level approximately 1 foot. A pool was then excavated on the downstream site of each weir.

Expected Benefits - These structures provide holding sites for adults prior to spawning and increases rearing capacity for young fish, thus increasing production. In addition to providing deeper water, these structures provide a variety of water velocities, and instream cover. Many times trees were placed over the pools to enhance cover as discussed earlier.

EXAMPLE 2 - CROOKED RIVER

Description - A Hewitt Ramp was used in the same type of sites as other log weirs.

Treatment - The Hewitt ramp is a modified log weir. 2″ x 12″ x 8′ planks replace the wire mesh and filter cloth. The main log is keyed into each bank as with the previously described log weir. A second log is buried 1′ - 1 1/2′ deeper about 5′ upstream from the main log. 2″ x 12″ x 8′ planks are then nailed to the two logs the entire width of the stream. The structure is then backfilled with streambed material.

Expected Benefits - The benefits are the same as with log wiers.

EXAMPLE 3 – RED RIVER

(Rock Deflectors)

Description – Rock deflectors were typically used where the substrate contained high proportions of large material mixed with gravels. These reaches provided few resting or spawning sites. Reaches selected for this treatment generally not conducive to installation of log weirs.

Treatment – A track mounted backhoe was used to move and shape larger streambed material into deflectors and/or rock weirs.

Expected Benefits –This treatment results in improved resting and holding sites for adult chinook prior to spawning and improved spawning sites where large material has been removed leaving suitable areas of gravel. Redds were located in these areas immediately after construction.

PROBLEM #4 - FISH PASSAGE BARRIER

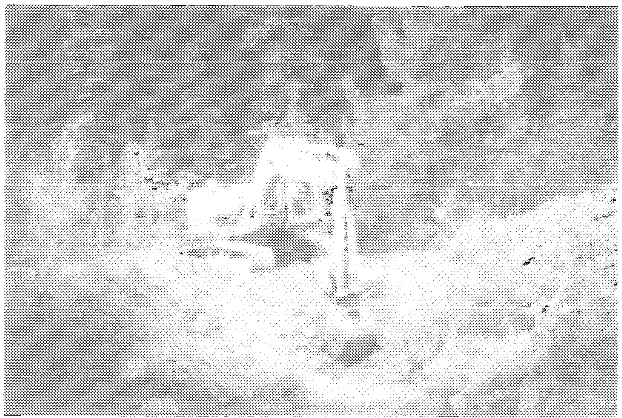
Description - An existing culvert on Crooked River was blocking access to approximately 4,500 square yards of useable steelhead spawning gravel.

Treatment - The site was surveyed and a bridge was designed using U.S.F.S. funds. BPA funding was used to remove the culvert and construct a bridge during 1984.

Expected Benefits - Access for spawning steelhead was provided to an additional 4,500 square yards of useable spawning gravel. Potential increase smolt production for Crooked River is 18,690 annually.

OFF CHANNEL REARING - CROOKED RIVER

BEFORE



AFTER

Description - A pond existed near the stream but with no connection to the stream. Water temperatures and depths appeared suitable for rearing salmonids. There was a constant exchange of water through the pond from inter-gravel flow.

Treatment - An open channel was constructed through the dredge tailing connecting the pond to Crooked River.

Expected Benefits - The side channel and pond will provide a refuge for young fish during spring runoff. It should also provide a preferred rearing area for chinook.

DISCUSSION

Monitoring Needs - In some instances, several different levels of treatment were used on a given problem to evaluate the effectiveness of each. The following is a brief summary of treatments which will be monitored by the project crew in the future. This will supplement the long term population monitoring being carried out by I.D.F.G. The primary objective of this monitoring is to evaluate effectiveness of the structures in creating the habitat features they were designed for, not to determine overall fish population trends.

1. Bank stability treatments in meadows. Three levels of treatment were carried out.

   a. Minimum treatment consisted of fencing, planting unrooted willow cuttings, and seeding.

   b. Moderate level of treatment included placement of boulders at selected points along an eroding bank with seeding and planting of unrooted cuttings inbetween. The whole area was then fenced.

   c. The most intense treatment involved placing a continuous row of boulders at the toe of an eroding bank then backfilling behind the boulders with streambed rock. The eroding upper bank was then pulled down with a backhoe and shaped by hand. The whole area was then seeded, fertilized, mulched, and containerized shrubs were planted.

2. Boulder placements. Boulders were used in several different habitat and configurations. Project personnel will sample these sites either by electro-fishing or snorkeling to evaluate gross differences in use. Sites to be evaluated include mid-channel placement vs. streambank placement; riffle placement vs. deep run placement; individual boulders vs. clusters.

3. Log Weirs. The following minor modification to the basic design were tried and will be evaluated in the future.

a. Log with wire mesh and filter cloth upstream;

b. Log with 2" x 12" planking upstream;

c. Log with no upstream materials

d. Logs installed with mud sills and wire mesh upstream and rock filled cribs on the end (earlier Forest Service project).

These variations will be monitored for differences in stability and maintenance requirements. They will also be sampled for any gross difference in fish use. The tailouts of pools created during construction will be monitored for collection of suitable spawning gravels.

4. Deflectors constructed from streambed material. The primary need here is to monitor for long term stability of the structures and occurrence of spawning gravels made available during construction. Chinook salmon redds were observed at some of these sites the year the deflectors were constructed. We will evaluate whether the gravel stays in place or is flushed out during the next spring runoff season.

5. Logs and trees placed for cover. Several variations were used and need to be evaluated for both fish use and longevity. These include: tops in water vs. trunk in water; parallel to flow vs. 20° - 45° into stream; cabled to bank vs. not cabled in place; placement in pools below log weirs vs. placement in pools above log weirs; and placement perpendicular to the stream vs. angled downstream.

6. Riparian revegetation. Survival of containerized shrubs needs to be compared with survival of unrooted cuttings. We will also monitor variation in survival among species planted both cuttings and containerized stock. Variation in success of seeding on different sites will be monitored.

7. Off channel rearing. The pond connected to Crooked River this year will be evaluated visually or by snorkeling to determine if it is receiving use by juvenile salmonids. Existing off channel ponds will be sampled either by snorkeling or electro fishing to determine use.

Other Activities Carried Out During 1984

1. Fish Habitat Surveys. Surveys were carried out for Reaches I, II, III, IV and V in Crooked River and reaches II, III-C, V-A, V-B in Red River. The survey information is summarized in Appendix 1. This information is essential in evaluating habitat improvement needs. At this time the habitat components we are emphasizing are pools, deep runs, and instream cover. Other items not listed in the summary but which we are treating include eroding stream banks, bank vegetation and spawning gravel.

2. Spawning Site Coring. Random sampling of fine sediment in potential spawning sites was carried out in both project streams. The information is on file at the Elk City District office. Percent fines less than l/4" averaged 30% - 35% in Red River and 23% - 35% in Crooked River. In Crooked River the sample which rated 35% was taken in the project area after this years work, which may have affected that sample.

3. Coordination - Project activities were coordinated with IDFG, (to provide adequate control sections); holders of unpatented mining claims (to avoid areas currently being worked (one case)); and landowners on Red River, (to arrange permission to carry out surveys and plan potential projects).

4. Contract work. Work requiring heavy equipment was carried out using equipment rental contracts on an hourly rate basis. This gave us the most flexibility in making on the spot modifications to meeet site specific needs. We utilized a "fish crew" hired by the Forest Service for all manual labor.

   A contract was developed with Washington State University to provide hydrologic analysis and design of a hydraulically sound artifical meander channel. The final analysis concluded that the channel can be built; however, the cost-benefit is low and risk factor for losing the stream into the gravel is high at this particular site. A final decision will be made shortly whether to build the channel here or to look for a more suitable site.

   Technical design information provided in the contract will be invaluable for use either in building the new channel, or when working with the existing channel.

SUMMARY OF ACCOMPLISHMENTS 1984

Treatment	Crooked River	Red River
Log Weirs	18	2
Boulder Weirs	9	4
Loose Rock Weirs	22	5
Random Boulders Placed	59	84
Boulder clusters	0	34
Anchored Debris	23	12
Debris jams treated	1	9
Off Channel Rearing	1 pond	0
Digger logs	0	
Bank stabilization	6,454 m^2	838 m^2
Rock & Boulder Deflectors	15	93
Log Deflectors	4	1
Bank Cover	1	
Plantings	350[a]	350[a]
	1,000[b]	1,320[b]
Instream Cover	0	10
Structures maintained	0	7
Fencing		321 m

[a] containerized shrubs
[b] willow cuttings

Summary of costs 1984

Cost estimates for the project are presented in three parts. First is simply the total annual contract cost divided by the number of structures. The second section is actual field cost (total cost minus planning, administration and overhead) divided by the number of structures. The third and most specific section is a summary of specific costs where itemized activities and costs are available.

1. $\frac{\text{Total annual cost Red River}}{\text{Total \# Structures Installed}} = \frac{\$85,781}{183} = \$470$ /structure

   $\frac{\text{Total Annual Cost Crooked River}}{\text{Total \# Structures Installed}} = \frac{\$72,889}{153} = \$475$ /structure

2. $\frac{\text{Total Field Work Cost Red River}}{\text{Total \# Structures Installed}} = \frac{\$64,781}{183}$ $755 /structure

   $\frac{\text{Total Field Work Cost Crooked River}}{\text{Total \# Structures Installed}} = \frac{\$51,889}{153} = \$340$ /structure

3l Specific Activity Costs.

Log weir construction (Crooked River)		$504 each
backhoe 3.5 hrs. @ $85/hr.		$297.50
boulders 4 @ $16.15 ea.		64.60
50' filter cloth		25.83
50' 2" X 2" wire mesh		41.15
plants, grass seed, fertilizer		10.00
crew time 3.5 hrs. @ $18.50/hr.		64.75
	total	$503.83

Boulder weir construction (Crooked River)		$300 each
backhoe 1.2 hrs. @ $85/hr.		$102.00
boulders 10 @ $16.15 ea.		161.00
crew time 2 hrs. @ $18.50/hr.		37 .00
	total	$300.50

Bank stabilization (Crooked River)		$7.18/m^2
backhoe 2 hrs. @ $85/hr.		$170.00
boulders 35 e $16.15 ea.		565.00
shrubs and grass seed		100.00
crew time 2 hrs. @ $18.5O/hr.		37.00
	total	$872.25

Log weir construction (Red River)		$308 each
backhoe 5 hrs. @ $35/hr.		$175.OO
crew 5 hrs. @ 18.50/hr.		92.50
30' filter cloth		15.50
30' 2" X 2" wire mesh		24.69
	total	$307.69

Rock wier construction (Red River)		$58.50 each
backhoe 2 hrs. @ $35/hr.		$52.50
crew 1 person hr. e $6/hr		6.00
	total	$58.50

Digger logs with cover (Red River)		$82 each
backhoe 2 hrs. @ $35/M.		$70.00
crew 2 person hrs. @ $6/hr.		12.00
	total	$82.00

Bank stabilization (Red River)		$16.30/m^2
backhoe 8 hrs. @ $35/hr.		$280.00
boulders 322 e $16.15 ea.		5,200.00
shrubs, seed, fertilizer		100.00
crew 12.7 crew hrs. @ $18.50/hr.		235.00
crane 16 hrs. @ $68/hr.		1,088.00
	total	$6,903.00

Structure maintenance (Red River) $30/structure

Crew - 5 person hours/structure 0 $6/hr.= $30 each

APPENDIX I

FISH HABITAT SURVEYS - 1984

Stream Name	Reach	Subreach	% Pool	% Riffle	% Run	% Pocket Water	% Instream Cover	Cobble Embeddedness	Comments
CROOKED RIVER	I	A	2	79	19	0	1.5	.50	From 5 Mi.Creek to Airstrip
CROOKED RIVER	I	B	8	72	17	3	2	.50	Along Crooked R. Airstrip
CROOKED RIVER	I	A&B	42	45	6	7	3	.25	After 1984 Project from 5 Mi.Creek through Airstrip
CROOKED RIVER	II	A	10	50	40	0	2	.50	New Bridge to Relief Creek
CROOKED RIVER	II	B	5	78	17	0	1	.50	Private land to Narrows
CROOKED RIVER	III		16	39	45	0	12	100	From Pond to Meanders
CROOKED RIVER	IV		51	18	31	0	0	.50	Meanders
CROOKED RIVER	V		22	17	36	25	1	.50	From Meanders to Mouth
RED RIVER	II	A	16	10	10	64	3	75	From campground-downstream
RED RIVER	II	B	16	24	23	37	13	50	Natural K-Dam Reach
RED RIVER	II	C	23	26	21	39	13	75	Natural K-Dam to Steckner C
RED RIVER	II	D	17	23	37	23	14	50	Steckner C. to Silt Trap
RED RIVER	II	E	21	14	60	5	20	50	Silt Trap through Meadows
RED RIVER	II	F	8	14	75	3	15	50	From Meadow to Ranger St.
RED RIVER	III	C	18	41	41	0	1	50	Mullens Ranch
RED RIVER	V	A	2	29	69	0	10	50	Gibbler Ranch
RED RIVER	V	B	42	17	41	0	8	50	Wilkerson's Little Ponderosa Ranch

SOUTH FORK SALMON RIVER

TRIBUTARY FISH BARRIER REMOVAL

PROJECT

1984

ANNUAL REPORT

TERRY HOLUBETZ

IDAHO DEPARTMENT OF FISH AND GAME

AND

JACK G. FISHER

CONSULTING FISHERIES ENGINEER

PROJECT COOPERATORS

IDAHO DEPARTMENT OF FISH AND GAME

BOISE NATIONAL FOREST

BONNEVILLE POWER ADMINISTRATION

Agreement DE-AI79-84BP13381

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ABSTRACT

NEPA compliance caused considerable delay in initiating this project in 1984. Barrier removal to be completed in 1984 by the Boise National Forest on Dollar and Six-bit Creeks was postponed. Barrier removal to be completed on Johnson Creek in 1984 was greatly delayed, and the work crew was not able to start the project until October 15, 1984. Unusually cold and stormy weather caused ice to build up on the stream banks and made access to the migration barriers extremely difficult. As a result of the late starting date and the cold weather, it was not possible to complete the barrier removal work on Johnson Creek. A major portion of the work was completed on Johnson Creek in 1984, and the project is expected to be completed September 1985. Summer chinook fingerlings will be stocked in the high quality habitat above the barrier in Upper Johnson Creek in the summer of 1985. The Boise National Forest developed plans in 1984 for the barrier removal work to be done in 1985. This annual report provides a summary of the progress achieved in 1984. A completion report will be issued at the end of 1985.

INTRODUCTION

Fish migration barriers formed by rock and natural debris are blocking access for adult salmon and steelhead to significant quantities of high quality spawning and rearing habitat in tributaries of the South Fork of the Salmon River. Much of this habitat supported large numbers of summer chinook salmon and summer steelhead as recent as the 1930's and the 1940's.

Selective removal of rock and woody debris at many of these barriers would allow adult salmon and steelhead to pass upstream to utilize these important natural production areas.

Idaho Department of Fish and Game entered into an agreement with Bonneville Power Administration to remove selectedmigration barriers in the South Fork Salmon River Drainage in 1984, and arranged to contract portions of the project to the Boise National Forest and to Jack G. Fisher, Consulting Fishery Engineer.

Mr. Fisher's report is included to illustrate the progress achieved on Johnson Creek in 1984.

Completion Report

Drilling & Blasting Selected Migration Barriers

Johnson Creek -- Valley County, Idaho

Project 06-68-605

November 1984

Prepared by

Jack G. Fisher, P.E.
Consulting Fisheries Engineer

Anchorage, Alaska

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Background

Several partial or complete blocks to upstream migrating anadromous fish were previously identified by Idaho Fish and Game. Department personnel prior to commencement of this project. Some detailed study had been made to determine the extent of the barriers and at what flows they presented a block to upstream migration.

These barriers were caused by natural rock slides and consisted of large boulders that had fallen into the stream and in most cases keyed together. Most of the rock in these barriers is relatively young with respect to water erosion and did not show the rounding effect that older water-eroded stones and boulders show in the lower reaches of the drainage.

For purposes of clarity in this report the designated barriers have been numbered 1 through 4, with barrier 1 being located about 15 miles above Yellowpine along the road and barriers 2, 3 and 4 (numbering upstream) located in the canyon about 18 miles above Yellowpine and within the first l/4 mile below the confluence of Trout Creek and Johnson Creek.

Methodology

Selective drilling and blasting of individual rocks to create lower overpours, jumping pools and escape avenues above the falls was the means selected to alleviate the problems caused by the rock falls. Two Pionjar Model 120 drills were used on this project. Integral bit-type drill steel in 2-, 4-, and 6-foot lengths was employed. Although none of the rocks to be removed required holes to be drilled in excess of 4 feet, the location of some of the holes rquired the use of 6-foot steel to obtain a 4-foot hole. The blasting agent was 40% strength dynamite in l-inch-diameter sticks. Detonators were electric and were used in delay with the maximum delay being 5 milliseconds. The crew consisted of two drillers, one powderman/foreman and an engineer.

All dynamite and caps, with the exception of the amount used daily, was stored in a locked power magazine located two miles from the closest work site.

Access to barriers 2, 3 and 4 from the road was down a ridge to the creek. Distance was about 1/2 mile with an elevation difference of about 600 feet. Without packs the normal transition time for accessing the site was about 20 minutes down and 35 minutes up. This of course depended on the snow cover and the amount of frozen ground that had to be traversed. Barrier 3 required wading Johnson Creek to get to the work site. Access to barrier 1 was relatively easy as the work site was within 150 feet of the road, and only a lo-foot-high bank separated the bed of the stream from the roadway.

Following is a description of work done at each barrier in the chronological order that work was performed.

Barrier 2

Drilling equipment was packed into the site on the afternoon of Monday, October 15, 1984. Site reconnaissance of all barriers was made that day. Actual work commenced on October 16. Barrier 2 consisted of a large rock fall that created an island at low flow with approximately 50% 0f the flow on each side of the rock rubble island. Falls from this area were about 8 feet in height with inadequate jumping pools on either bank. It was determined that the removal of one large rock on the left bank upper falls and removal of a rock at the base of the overpour would lower the water level above the falls, thereby putting the majority of the water over the new falls on the left bank. The first shot consisted of twelve 2- to 4-foot holes and effectively lowered the falls by 2 feet. In shooting, a large rock under the falls was dislodged by the increased flow and this rock moved into a pool below the falls. A second round of drilling and shooting was required to lower the upper pool level still further and remove the rock that had fallen into the jumping pool. The second shot consisted of seven 2- to 3-foot holes and effectively cleaned up the falls and created a 2.5-foot and a 3-foot falls with a jumping pool between where there had previously been a single 8-foot falls. Also, all of the creek flow was now on the left bank, eliminating a low flow condition of a split flow. This correction also negated the attraction flow on the right bank where there had been an 8-foot falls over a very large boulder.

This barrier is at the base of a large rock slide that shows indication of recent movement either from earth tremors or frost heave. Since this is an active slide area, the falls will require continued surveillance prior to upstream salmon migration to assure that the barrier area remains free of partial or total blocks to upstream migration.

Barrier 3

Barrier 3 was located about 150 yards upstream of barrier 2, but direct access to the site with the drilling equipment was not possible by walking along the creek due to rough terrain. Therefore, all of the equipment was packed back to the road and then back into the canyon to a point where it was possible to wade the creek. On October 17 all equipment was transferred to barrier site 3 and drilling commenced. This barrier was not unlike barrier 2 in that the stream was split and there were two falls. The falls were each about 7 feet high with the major portion on the left bank. It was determined that the right bank falls provided the best opportunity for correction, and the major effort was concentrated here. One very large round boulder had wedged in the right bank channel, and this rock, along with a ledge rock on the right bank, was removed in the first blast. Forty-four holes were drilled from 2 to 4 feet deep for the first shot. The first shot was made in the afternoon of October 18. After the shot was made, it was determined that some fragments of the ledge and the large key boulder were still too large to assure movement by high water; therefore, a second round of 10 shots was made to further correct the new channel. This second shot effectively broke up the large rock so that high water will move the small rock out of the new channel. Terry Holubetz then requested that some correction be made on the left bank falls to provide an escapement pool above this falls. This correction was made on October 19. With the cleaning of the right bank falls area of shot rock by high water next spring, it is anticipated that the right bank will provide a series of small cataracts and pools that will pass adult fish. The left bank falls was lowered only about 1 foot in height but provided a pool at the top of the falls. The area immediately above the falls has about a 36% grade so further correction would not be prudent unless the large pool below the falls is raised; this is virtually impossible given economic as well as geologic and topographic constraints. Equipment was moved out of the canyon during the afternoon of October 19.

Barrier 4

This barrier, as was pointed out from a distance during the preliminary walk-through, was determined not to be a barrier at the flow observed and is probably not a migration barrier at any flow when considered with the entire cataract area. The location of this barrier was just below the confluence with Trout Creek. Grant Christensen agreed with this assessment. There is a distinct possibility that whatever rock or rocks that had constituted the barrier during the early investigations had moved so that the barrier no longer existed. Correction in this 40% cataract would be difficult at best. The entire cataract consists of large boulders, and they appear to be well keyed in the riverbed matrix.

However, immediately below the original barrier location is a falls approximately 6 feet in height that should be corrected. No attempt was made to correct this falls as it will require bridge, boat or wetsuit operations to get a crew into the area. Due to an extreme amount of ice on the rocks at the time this project was under way, only a cursory attempt was made to access this falls. Terry Holubetz advised that he did not feel that this barrier was a total block as there is an excellent jumping pool below the falls and an adequate escape pool above the falls. If at some future date it is decided to correct this falls, it should be done in late August or early September to alleviate the ice and cold conditions that existed while this project was under way. Access will be by temporary bridge across the stream or by boat or by personnel in wetsuits. Equipment will probably have to be lowered to the falls from a cliff on the left bank unless a bridge is constructed.

Barrier 1

This barrier consisted of two falls about 4 feet in height with no jumping pool in between. It was caused by large rounded boulders being wedged together and creating thin overpours over the boulders. The stream was spread out over several falls with none providing adequate water for fish transportation. The correction desired was to concentrate some of the flow and provide a resting area and jumping pool between the falls on the left bank. Drilling started in late afternoon of October 19, and one blast consisting of 6 holes in two small boulders was made that day. On October 20 the remaining boulders were blasted out in two shots of 4 holes each. This resulted in approximately one-half of the river flow being concentrated in the area of the blasts with the falls being reduced to two 2-foot falls with an adequate jumping pool between them.

Because this part of the project was located near the road, before each blast a truck and driver were placed to block the *road* about l/4 mile above and below the work area to preclude any accidents to people or vehicles using the road.

All equipment was packed up and removed from the job site on the afternoon of October 20. This completed the project work to be done this year.

Weather

Weather during the period that the project work was done was mostly cold, cloudy and windy, with some intermittent periods of snow and occasional sunshine. The sun rarely reached the work sites in the canyon. Access to the canyon sites was usually difficult in the early morning due to the steep terrain and frozen ground and/or snow cover. There was no trail and little brush to provide hand holds. After a snowfall, footing was even more treacherous. No accidents occurred either in accessing the sites or doing the work.

On the second morning (October 16) the overnight low temperature was 17° F, and the boulders in the creek had ice over them, making working on them very precarious. The ice remained on the boulders throughout the time project work continued. The low temperatures also caused a decrease in flow in the creek, and the ice on the boulders and in the stream created some small changes in flow patterns.

Low temperature recorded during the time the work was under way was 14° F and the high temperature recorded was 42° F. On four of the five days spent on the project, the temperature never rose above freezing. Snow fell during two days of project work.

Summary and Conclusions

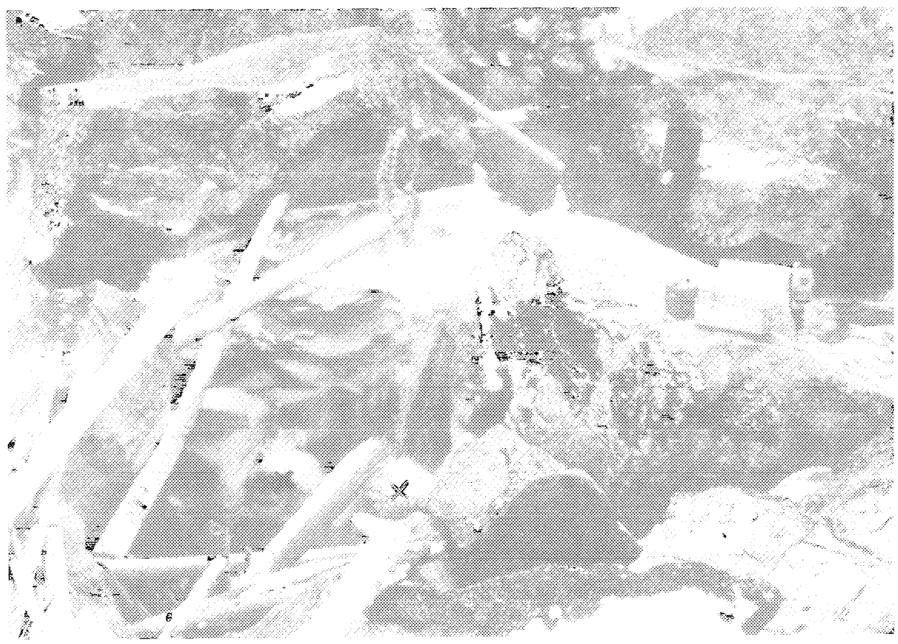
The project went much as planned and with the exception of some weather problems, the work progressed well. The contractor provided good equipment in adequate quantities, complete with spare parts. The contractor's crew was well organized and accomplished the work in a professional, competent way and conducted all operations in a safe, efficient and cost-effective manner.

Future projects like this should give serious consideration to performing the work during the late summer months rather than in freezing conditions. Although there were no accidents, the ice and snow contributed to some delay in accessing sites as well as conducting the actual work. A better time for doing future work like this and especially in mountainous areas would be prior to October 1. In this way flows will be low, but ice and snow would not be a problem.

Finally, it appears that barriers 1, 2 and 3 have been corrected to allow for upstream migration of anadromous fish. Barrier 4 should be reinvestigated at the first opportunity. Barriers 1, 2 and 3 should be monitored as soon as possible after spring runoff to determine if the rock fragments moved out as planned and the escapement paths remain open. Further correction may be required if this removal of rock allows other boulders to move during high flows. Past experience indicates that minor falls corrections such as those done on Johnson Creek usually require some minor work the second year to complete the correction desired. Since the area that was included in this project has some active slides and a relatively unstable stream bed, the inspection following this year's project is even more critical.

'hoto 1-5   Barrier No. 2

'rior to blasting. Note left and
·ight bank falls.



'hoto 1-4   Barrier No. 2

)rilling to open new water path
/here small overpour shows just
nder driller. Rocks marked "X"
lso removed.

hoto 1-7   Barrier No. 2

;eneral view showing ice and
now covering rocks in vicinity
f work.

Photo 1-14 Barrier No. 2

Taken after first blast. Note increased water flow on left bank.

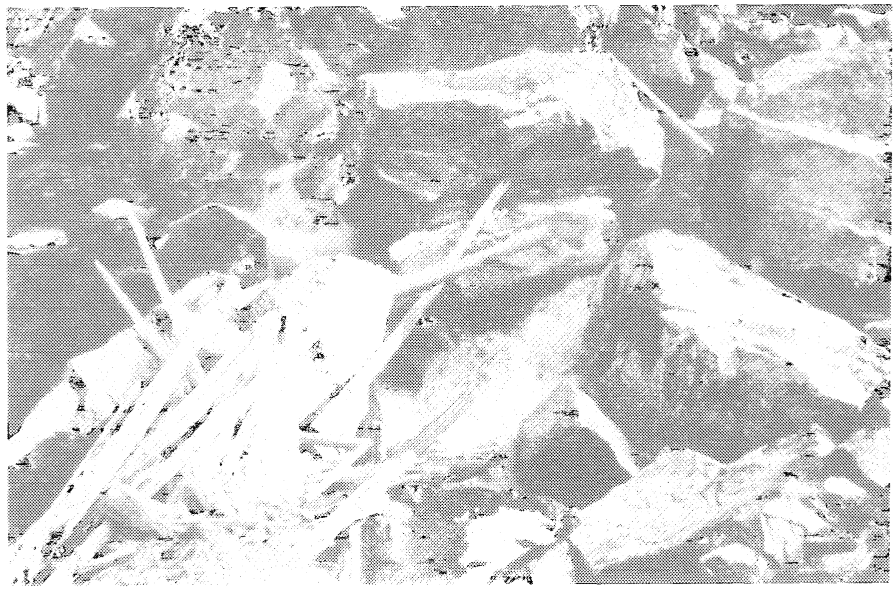


Photo 1-15 Barrier No. 2

After second blast. Note change in configuration of falls. Water here enters from right to first jumping pool above main pool below all falls. Water exits to left. Right bank falls has ceased to flow.

Photo 1-16 Barrier No. 2

Shows exit from first jumping pool above main falls.

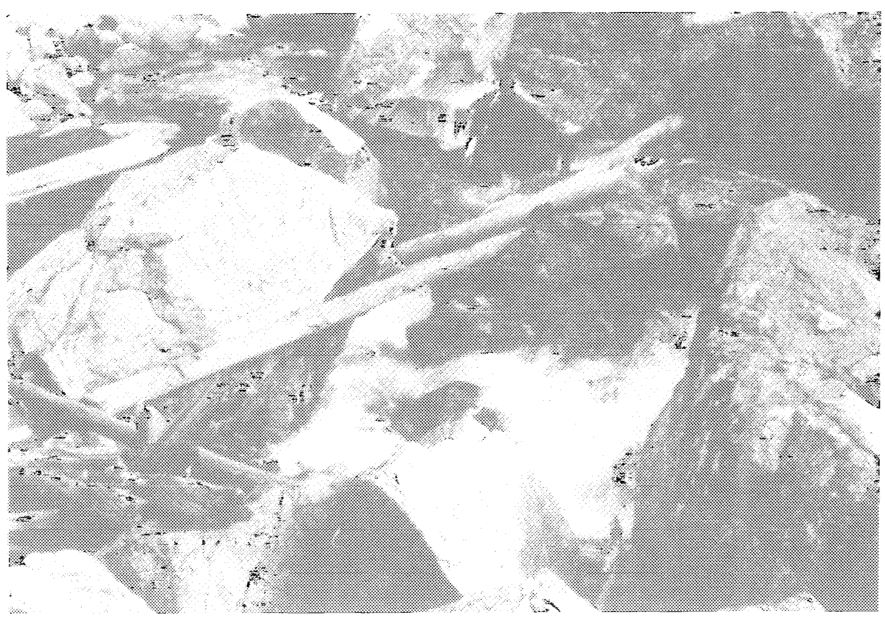


Photo 1-20 Barrier No. 3

Drilling in bypass area on right bank. Note ice and snow on rocks. Main flow and falls are to left.

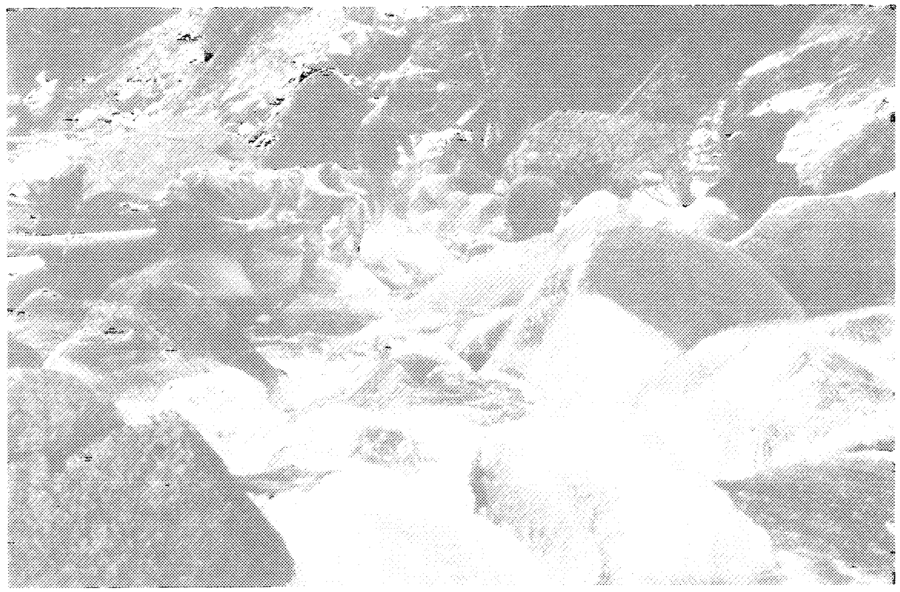


Photo 1-22 Barrier No. 3

Drilling in bypass area on right bank. Main flow of stream exits photo at lower left center.

Photo 1-25 Barrier No. 3

Loading holes in bypass area on right bank.

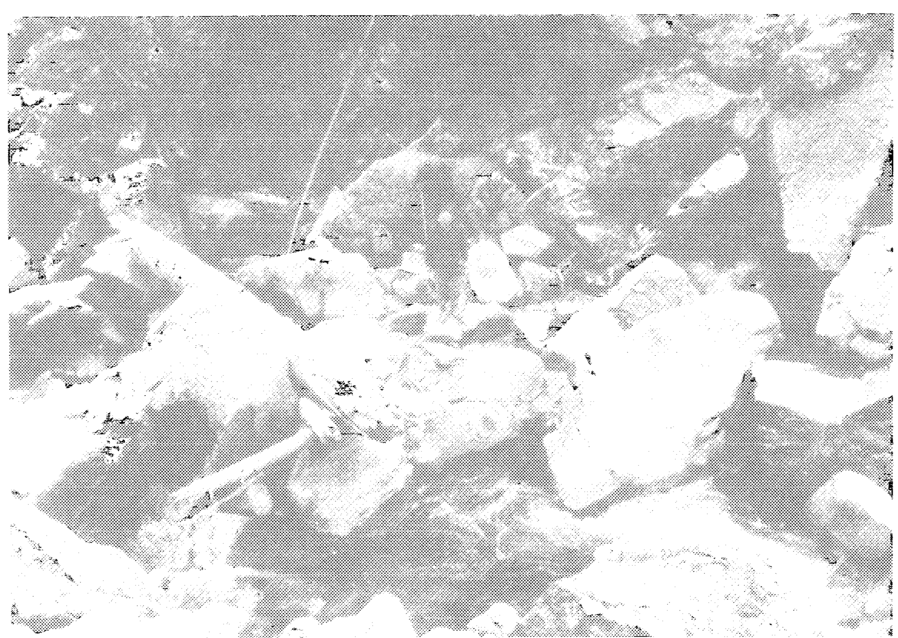


Photo 1-27 Barrier No. 3

After first shot. Note repositioned log.

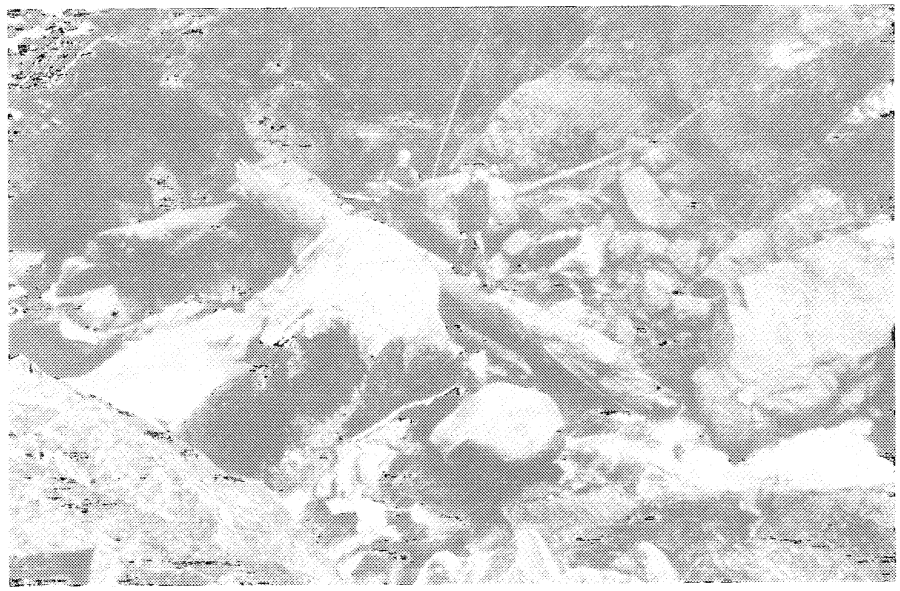


Photo 1-33 Barrier No. 3

After second (final) shot in main bypass channel. Again note repositioned log. It is expected this log will go out in high water. Also small, loose rock should wash out.

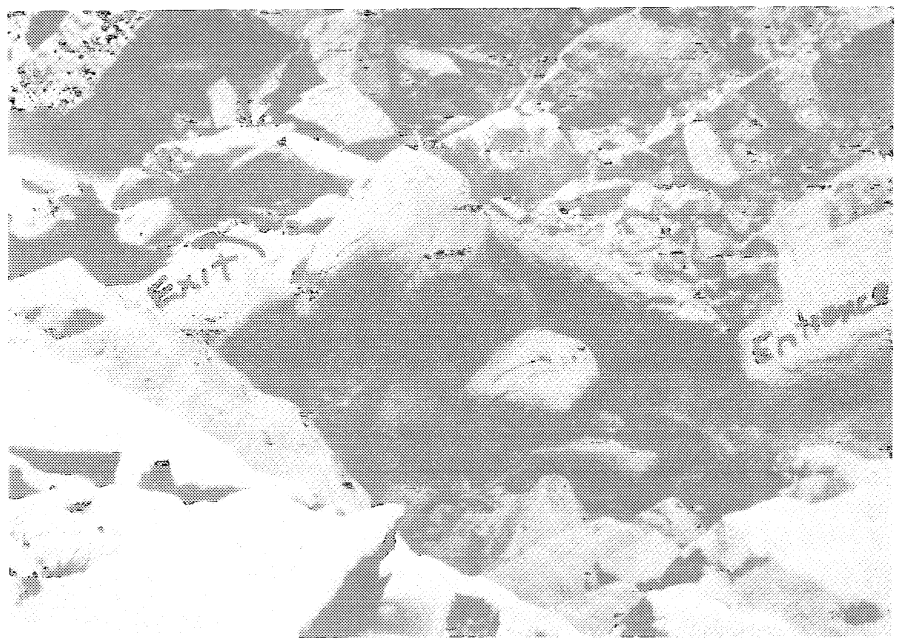


Photo 1-28 Barrier No. 3

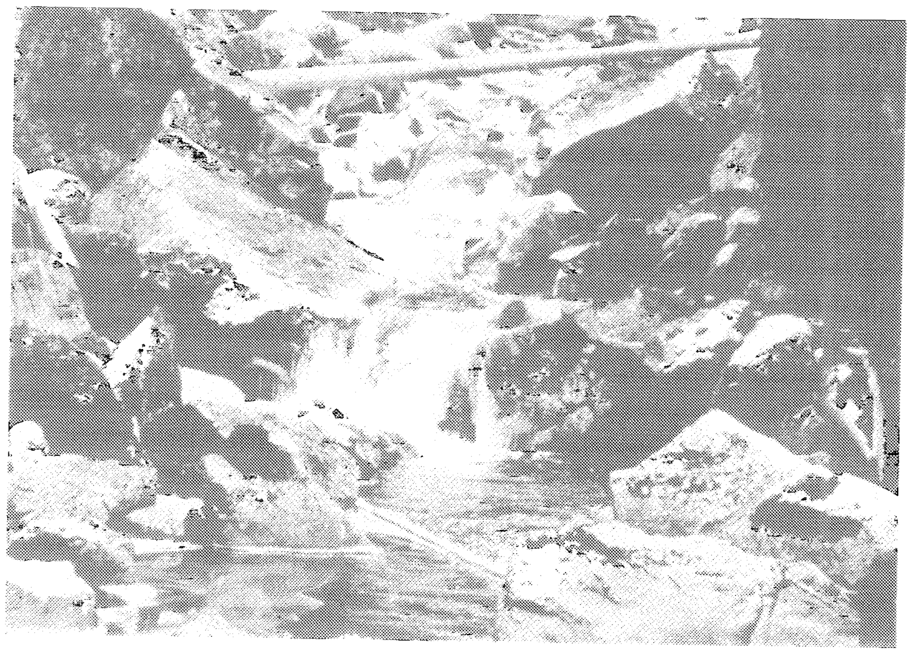
Drilling at top of falls to provide pool for fish jumping main falls on left bank.

Photo 1-17 Barrier No. 4

General view of barrier which was not corrected. Gradient from base of falls to next upstream pool area is 36%±. Correction here should be on left bank where marked.

Photo 1-23 Barrier No. 4

Close-up of barrier. Note steep stream gradient above overpour.



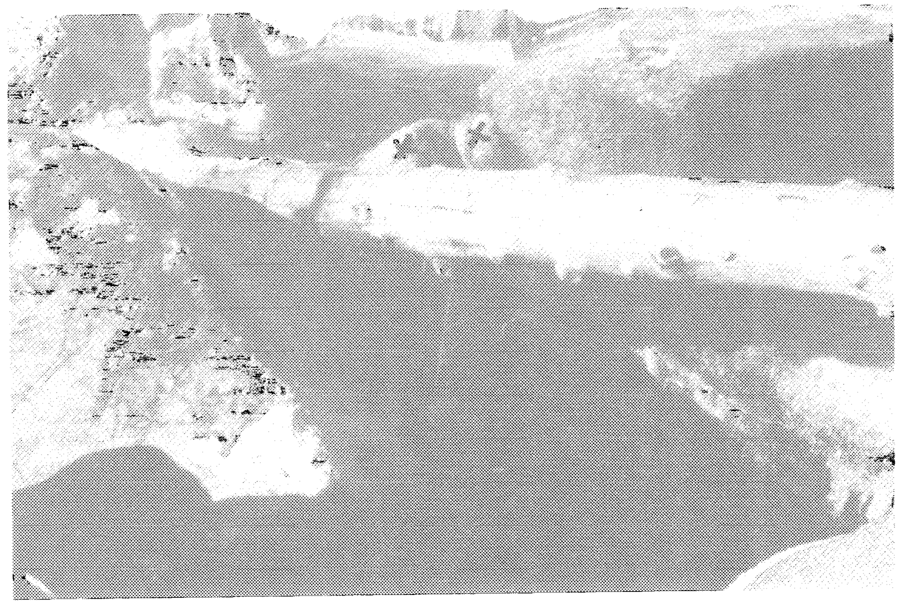


Photo 1-36   Barrier No. 1

Photo shows rocks to be removed in first shot to lower upper pool and provide new attraction flow. Rocks marked "X" removed.

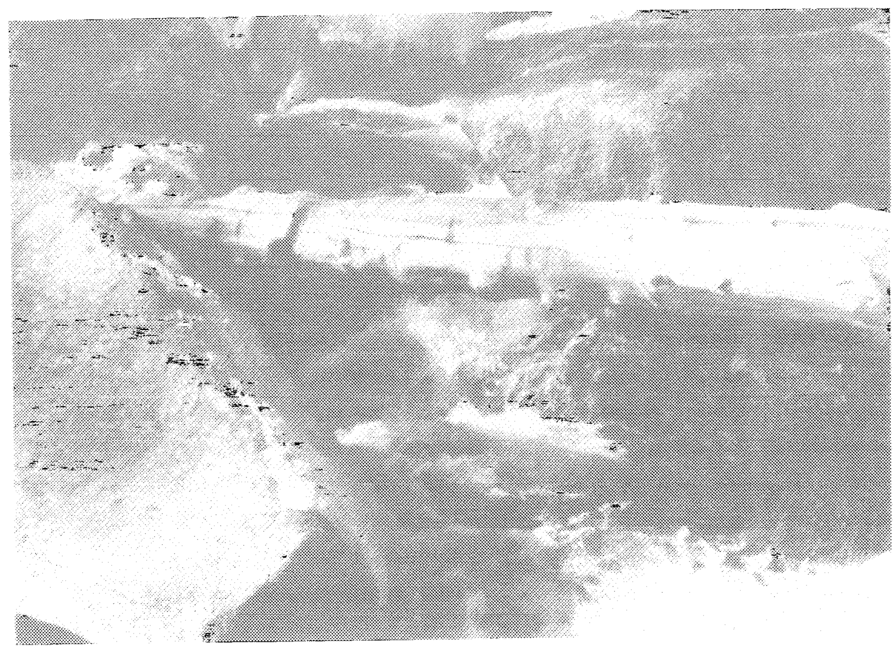


Photo 2-6   Barrier No. 1

Results of first shot showing water in new channel. Existing pool in lower foreground.

Photo 2-2   Barrier No. 1

Rock marked "Y" being drilled to provide auxiliary water to attraction flow created by first blast in Photo 2-6.

Photo 2-7 Barrier No. 1

Shows additional attraction water added by blasting out rock "Y" shown in Photo 2-2. Upper pool lowered about one foot.

Photo 2-9 Barrier No. 1

Shows new access route on left with pool in lower right center. Auxiliary water flow shown entering on right.

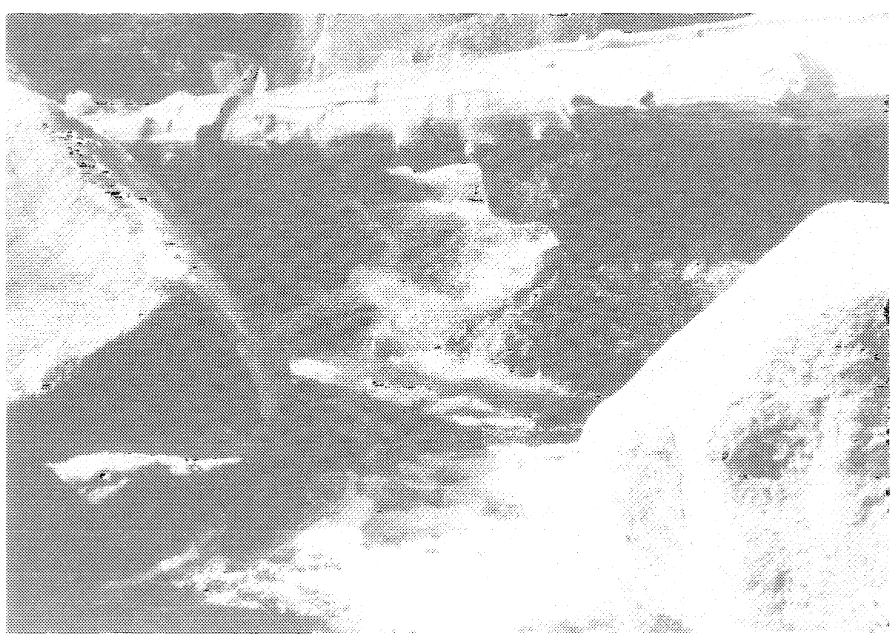


Photo 2-8 Barrier No. 1

View of new fish bypass route with resting/jumping pool in center foreground. Loose rock here will move out with high water.

ANNUAL REPORT: Project Number 83-415, Alturas Lake Habitat Improvement

Project Leader; Harvey L. Forsgren II

5 April 1984

ANNUAL REPORT: Project Number 83-415, Alturas Lake Habitat Improvement

Abstract

The first year of a two year study to determine the feasibility of augmenting stream flows in Alturas Lake Creek, during the summer and fall when natural flows are insufficient to meet irrigation demands and fishery needs, has been completed. All aspects of the feasibility study, including legal, biological, engineering, hydrologic and economic aspects, have been initiated.' To date, no aspect of the feasibility study has eliminated either of two identified alternatives: dam construction to provide storage capacity for fishery releases, and water right acquisition. The methods employed in the feasibility study and results of the investigations to date are detailed.

Introduction

An outstanding opportunity exists to enhance natural production of spring chinook salmon and reestablish sockeye salmon production in the Alturas Lake basin of the upper Salmon River. Diversion of flow from Alturas Lake Creek (ALC) for irrigation purposes annually dewaters the stream, reducing chinook salmon spawning and rearing habitat availability and eliminating sockeye salmon production potential. Two approaches have been suggested to resolve this conflict between irrigation demands and fishery needs. The first is construction of an outlet control structure on Alturas Lake to store spring runoff for release into ALC in late summer and early fall to accomodate upstream migrating and spawning chinook and sockeye salmon. The second approach is to acquire all or part of the water rights held on ALC for instream use by the fish, The first phase of this project, initiated April 1, 1983, is designed to evaluate the feasibility of implementing these alternatives, including development of cost and benefit information.

Study Area

Alturas Lake Creek drains 66 square miles of forested slopes of the Sawtooth and Smoky mountain ranges. It is a major tributary to the Salmon River, entering at Township 7N, Range 14E, Section 20, approximately 17 miles upstream from Stanley, Idaho, Flows from this drainage primarily originate as snow melt, beginning to increase in April from base flow conditions to peak flows in June and then quickly recede to near base flow conditions in August. These flows feed two morainal lakes, Alturas (838 acres) and Perkins (50 acres).

The drainage contains some of the best spring chinook and sockeye salmon habitat in the Salmon River basin. Unfortunately most of this habitat, some 8 miles of stream and nearly 900 acres of lakes, lies above the diversion dam and is inaccessible to these anadromous species, The water rights held on ALC total 37.84 cubic feet per second (cfs), date back to the 1930's, and are diverted from one point (ALC-I), Ditch capacity at ALC-1 is about 50 cfs, more than the average natural flows instream during the upstream migration and spawning periods of chinook and sockeye salmon.

Methods

Evaluation of the feasibility of augmenting stream flow in ALC has been divided into eight study segments, identified as "information needs." Applicable work tasks were then identified to meet the information need. Information needs, and methods used to resolve the needs are detailed below.

Legal Issues. Legal issues pertinent to flow augmentation, including water right acquisition, were identified and submitted for legal opinion to the U.S. Department of Agriculture, Office of the General Council and to the Idaho Department of Water Resources. Valuation of water rights will be determined by certified appraisal.

Instream Flow Needs. Instream flow needed to provide upstream passage, spawning, egg incubation and rearing are determined using an Instream Flow Incremental Methodology. A memorandum of understanding has been developed with the U.S. Fish and Wildlife Service to provide field assistance in data collection and computer analysis of that data.

Stream Habitat Inventory. The amount and quality of chinook salmon spawning and rearing habitat has been assessed using standard Region 4 Forest Service inventory methodologies, in which physical habitat parameters are summarized by 100 meter intervals. This production capability information will be used to refine expected benefit estimates.

Lake Habitat Inventory. A contract has been awarded to the Idaho Department of Fish and Game (IDF&G) to develop a model for estimating sockeye salmon production in the Alturas Lake system. IDF&G is also stocking Alturas Lake with juvenile sockeye, in anticipation that the flow conflicts will be resolved.

Preliminary Dam Design/Cost Estimates. U.S. Forest Service engineering and geotechnical staff will develop, from site surveys, preliminary dam designs and cost estimates, for the outlet control structure to provide storage capacity for fishery flows and modification, or reconstruction of the diversion dam necessary to: 1) deliver no more water than the decreed water right to the irrigator's ditch during the period of upstream migration, spawning and incubation, 2) concentrate flows into a single channel rather than dividing it between two channels, 3) provide for upstream passage at the diversion structure itself, and 4) screen downstream migrating juveniles from the irrigation system.

Impacts Associated With Impoundment. If a dam is constructed on the outlet of Alturas Lake to store water and regulate outflow from the lake there would be certain environmental costs. The effects of elevating the lake level on the lake shore and its associated values (e.g. beaches, developed recreation sites, timber, soils, visuals, cultural resources, etc.) will be assessed by an Interdisciplinary Team assembled by the Forest Service.

Hydrologic Relationships. U.S. Forest Service hydrological staff, from the Intermountain Regional Office, have provided assistance in study design, data collection and analysis to determine the hydrologic relationships between the primary inlet to Alturas Lake, the outlet stream and delivery to the point of diversion. Permanent gaging stations have been established at

Impacts Associated with Impoundment. Primary concerns with the storage alternative involve the impacts which the project could have on popular recreational facilities adjacent to Alturas Lake. To better define the extent of potential impacts, elevational surveys were completed at all recreational facilities that may be affected. Those surveys identified two possible areas of impact; a boat launching facility in the Smoky Bear Campground and the Inlet Beach picnic area. Topographic maps are being developed for the inlet area to help in the assessment of the magnitude, and mitigatability, of the impacts associated with impoundment.

Hydrologic Relationships. Staff gage/stage relationships have been developed for the three permanent gaging stations. Those relationships will continue to be refined as more information is collected at each site. Water production and evaporation estimates indicate that the flows necessary to provide the desired storage capacity are available every year (i.e. water storage requirements, represent only a small portion of spring runoff flows).

Maintenance Responsibility for Structural Improvements. The Forest Service (FS) has met with representatives of the Idaho Department of Fish and Game (IDF&G) and the National Marine Fisheries Service (NMFS) to discuss maintenance responsibility for any structural improvements (e.g. dam, fish screen, fishway) associated with resolving the instream flow conflicts on ALC. NMFS felt they would probably be able to fund maintenance of an ALC-1 fishscreen. IDF&G expressed the possibility that they may be able to accept maintenance responsibility for a dam, as part of the function of the Sawtooth Hatchery being built near Stanley. The F.S. expressed the possibility that they may be able to assist in light maintenance and operation of the dam by using campground patrol personnel that are at the site daily. Maintenance responsibility will be firmed up at the time of alternative selection.

Summary and Conclusions

The feasibility of augmenting stream flows in Alturas Lake Creek to enhance natural production of chinook salmon and re-establish sockeye salmon in Alturas Lake is being evaluated in a two year study. The report presents the results of the first year of that study. Legal, biological, engineering, hydrologic, and economic feasibility analyses have been initiated to determine the costs and expected benefits of two alternatives to resolve a conflict between irrigation diversion and fishery needs. The two alternatives being considered are: 1) construction of an outlet control structure on Alturas Lake to store spring runoff for release into the stream necessary to accomodate upstream migrating and spawning chinook and sockeye salmon and 2) to acquire all or part of the water rights held on Alturas Lake Creek for instream use by the fish. Results of the feasibility study-to date have not eliminated either of these alternatives. It is likely that the value of the results of the feasibility work will be to suggest which alternative is most attractive from a cost/benefit view, or environmental soundness perspective.

three locations in the ALC system. Other aspects of the hydrologic cycle (e.g. quantity of water produced in the watershed, amount of evaporation from Alturas Lake) have also been defined using standard methodologies.

Maintenance Responsibility for Structural Improvements. Maintenance responsibility for any structural improvements built as a result of this project will be negotiated among the Forest Service, Idaho Department of Fish and Game, the National Marine Fishery Service, and Bonneville Power Administration.

Results/Discussion

Significant progress for the first year of the feasibility study phase of the project is summarized by information need below.

Legal Issues. Legal issues pertinent to instream uses of water, water developments, and water right acquisition have been addressed. No legal issues were surfaced which would preclude implementation of either of the identified alternatives. A contract has also been developed, and will be awarded in the near future, to have a certified appraiser familiar with water right evaluation, appraise the value of Alturas Lake Creek water rights.

Instream Flow Needs. Instream Flow Incremental Methodology techniques have been employed to define stream flows necessary to meet various levels of upstream migration, spawning, incubation and rearing criteria. Results of these studies suggest that either of the identified alternatives would provide sufficient flows instream to effectively mitigate the impacts of ALC-1 on anadromous fish production capability.

Stream Habitat Inventory.

Habitat inventory data suggest that in the Alturas Lake system rearing habitat is the factor limiting chinook salmon production. More than 80 per cent of the suitable rearing habitat lies above the diversion, and is therefore, currently inaccessable to chinook. There is adequate spawning habitat above the diversion to seed this rearing habitat. The increase in production capability associated with accessing this habitat is estimated at 120,000 to 160,000 chinook smolt/year.

Lake Habitat Inventory. Completion of a model to estimate the potential production of sockeye salmon in the Alturas Lake drainage is anticipated by July of this year. Preliminary estimates suggest the increase in production capability associated with accessing this habitat to be at least 500,000 sockeye smolt/year.

Preliminary Dam Design/Cost Estimates. Site surveys at the outlet of Alturas Lake and at ALC-1 have been completed. Engineering staff are currently developing a report which will present: 1) a discussion of general dam requirements, 2) alternative dam types and associated cost estimates, and 3) conclusion and recommendations for the dam site at the outlet and for the diversion structure.

Summary of Expenditures

ACTIVITY	COST
Resolution of Legal Issue	$ 500
Instream Flow Assessment	$3,500
Stream Habitat Inventory (Chinook Production Estimate)	$6,500
Lake Habitat Inventory (Sockeye Production Estimate)	$3,000
Preliminary Dam Design/Cost Estimates	$1,000
Impact Evaluation	$1,000
Hydrologic Relationship Definition	$ 500
Resolution of Maintenance Responsibilities	$2,500
Water Right Appraisal	Contract Not Let
Administrative Costs	$1,500
	$20,000